Vol. VI. — No. 7-8. July-August 1924.

BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

[624. (09.1 (.43)]

Notes on the construction of railway bridges over the Rhine, [1]

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Figs. 1 to 91, pp. 497 to 547.

These notes were prepared during a stay in the occupied portion of Germany when acting as superintendent of the line under the Franco-Belgian control of the Rhenish Railways at Aix-la-Chapelle.

They give a short account of the various railway bridges constructed over the Rhine from the Dutch frontier up to and including the bridge at Worms, and to this account is added a critical survey of the evolution of the various forms adopted.

Without pretending to exhaust such a vast subject, we hope, however, to give a general insight into it, and show in chronological order a true sequence of a remarkable and extremely curious evolution of the various forms of these structures.

If it is often somewhat bold to criticise *a priori* any particular arrangement in construction, because the complexity of the factors involved justify several solutions, it is always interesting to analyse the ideas which have influenced the author in his choice of a design. These notes therefore make no pretention at being pedantic, but should be looked upon simply as our personal reflections as regards these great structures which we have been able to study and become familiar with in the course of our duties.

I. — BRIEF DESCRIPTION OF THE VARIOUS STRUCTURES.

§ 1. — Bonn and Dusseldorf bridges.

The Bonn and Dusseldorf bridges, being road bridges, can hardly be said to be interesting so far as railways are concerned. They are, however, the pioneers of the large open braced arch type, having two-hinged joints, that were

(1) Translated from the French.

built over the Rhine, and consequently form the first interesting step in the construction of these great structures.

Contrary to the fundamental idea which prevailed later (Worms) in the design of main girders, the arches with a large span are not fitted with chord ties to absorb the horizontal thrusts. The equilibrium of the slender piers fixed in the river is maintained by abutting the long arches over the river against the flatter side arches.

The platform of the central arches is placed at an intermediate level near the springings, whilst the flatter side arches come entirely under the roadway. These structures, a summary description of which we will now give, were completed at the end of the year 1898.

Bonn bridge. — The *central span* of the Bonn bridge is composed of two braced arch ribs 187 m. 20 (614 feet) long (fig. 1), the distance between the centres being 9 m. (29 ft. 6 1/4 in.).

The depth of the girders is 10 m. 537 (34 ft. 3 in.) at their springing and 4 m. 8 (20 ft. 8 in.) at the crown, the rise of the lower boom or chord being 29 m. 60 (97 feet).

The two-hinged *braced arches* of the side spans have a length of 93 m. 60 (307 feet) (half that of the central arch), and a depth of 7 m. 67 (25 feet) at their springing at one end and 10 m. 63 (34 ft. 6 in.) at the other, giving a mean rise of 9 m. 15 (30 feet), which is about one tenth of the span.

The *platform* of the central span is suspended from the main girders and comes level with the first apex in the top boom.

Windbracing of the large span (fig. 2). — Generally speaking, the upper windbracing of the large arches is made up of cross frames fixed in the vertical planes of the uprights and curved girder diagonals following the neutral axis of the top boom (fig. 3).

The cross frames are made up of two braced struts rigidly connected to the top and bottom booms and by the vertical members of the two ribs.

The frame is completed by means of two light angle irons fixed diagonally. It seems evident, however, that these light members, which are not even riveted together where they cross, serve no useful mechanical purpose in the structure. The lower flange of the girder, which falls rapidly *towards the ends*, is connected directly to the verticals of the main ribs.

The diagonal curved girders forming the upper windbracing consist of lattice girders joined together by plates where they intersect and attached by means of hinged connections to the top boom.

These diagonals are of square section with corner angles with single bracing on the faces made up of flat bars.

The angles are brought together at their extremities to grip the jointed coupling up plate (fig. 4).

Following the usual practice in the construction of other large structures, the top windbracing girder is considered as resting at its extreme ends on two rigid portals transmitting all transverse stresses to the supports fixed on the piers.

In the Bonn bridge the portals are situated in line with the third apex of the top boom (fig. 5).

We may further point out that as regards the *original details*, the box members are braced on the outside by single angle iron bracing with connecting plates fastened with three rivets at the ends of the member. We have not yet found the bracing diaphragms of this par-

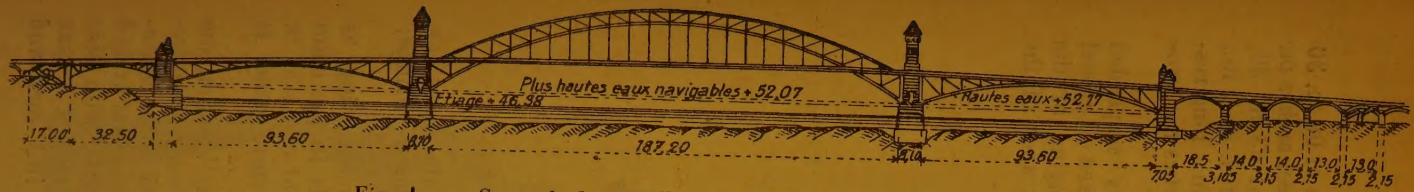


Fig. 1. — General elevation of the Bonn bridge over the Rhine.

Translation of French terms : Plus hautes eaux navigables = Highest navigable water level. — Hautes eaux = High water level. — Étiage = Low water level.

Fig. 2. — Bonn bridge.
General view of windbracing.

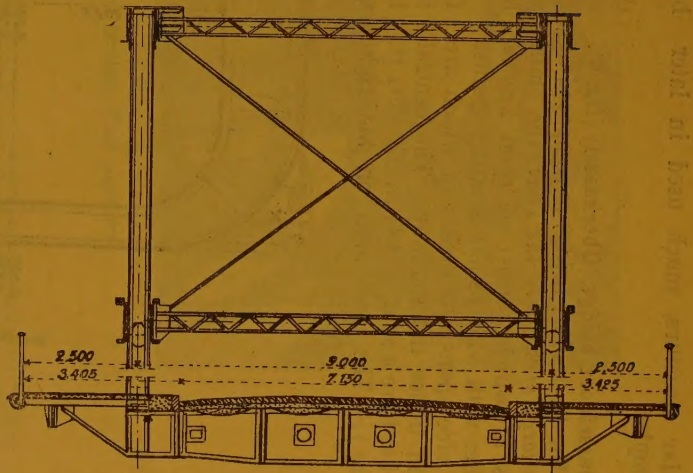


Fig. 3. — Cross section of the Bonn bridge showing windbracing cross frame.

ticular structure, much used in later examples.

Dusseldorf bridge (Oberkassel) (fig. 6). — The Dusseldorf bridge is composed of *two large spans over the river*, the main ribs of which consist of open braced arches with wide panels abutting against the side spans, the arches of which are fixed under the roadway. The central arches have a span of 181 m. 25 (594 ft. 7 in.). The steel arch on the right bank of the river has a span of 60 m. 36 (198 feet), and the three steel arches on the left bank have spans of 63 m. 36, 57 m. 02 and 50 m. 69 (207 ft. 1 in., 187 ft. 1 in. and 166 ft. 3 in.) long respectively. Each of these arches has two-hinged joints (fig. 7).

The *platform*, which is suspended from the main girders, is fixed on a level situated between the springing of the bottom boom and the first apex of the top boom (figs. 7 and 12).

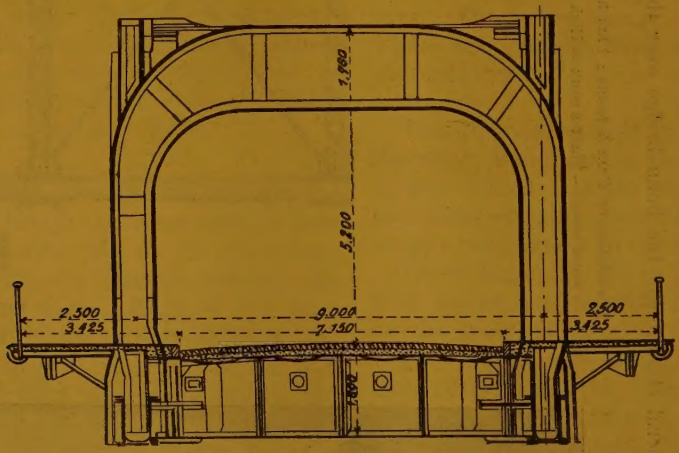


Fig 4. — Cross section of the Bonn bridge showing portal.

The *upper windbracing*, formed by means of curved girders fixed between the upper booms and the cross frames fixed between the top and bottom booms, is arranged in the same way as that of the Bonn bridge (fig. 10). The end portals in the Dusseldorf bridge are fixed, however, in the cross section of the second vertical of the main girders (fig. 11). As a result, the end panel only is not braced, whereas in the Bonn bridge, the *two* end panels are without bracing (fig. 12 and 13). The members are box shaped, as in the Bonn bridge, and the webs are braced on the face by single angle bars with intermediate plates (an improvement on the Bonn bridge) (fig. 14).

Another point worth mentioning, is that the number of panels in the main ribs being odd (25 instead of 24 as in the Bonn bridge), the centre panel is counterbraced.

As a reminder, we may mention the *road bridge at Magdebourg* (*Königsbrücke*), which was opened at the beginning of 1903. This has a central arched span of 135 m. (443 feet) with side arches of reinforced concrete of a span of 28 m. 50 (93 ft. 4 in.) each and

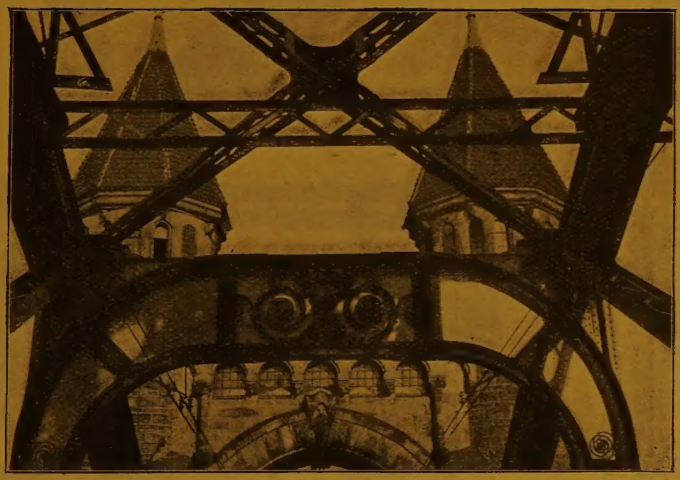


Fig. 5. — Bonn bridge. End portal.

Fig. 6. — Dusseldorf bridge. End portal.

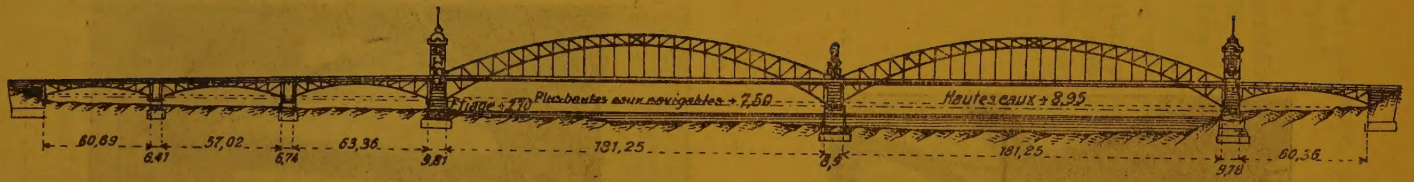


Fig 7 — General elevation of the Dusseldorf bridge over the Rhine.

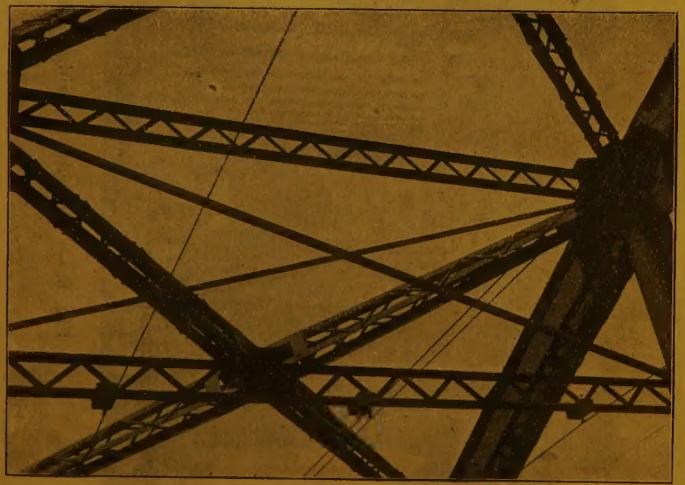


Fig 8. — Dusseldorf bridge. View of the windbracing.

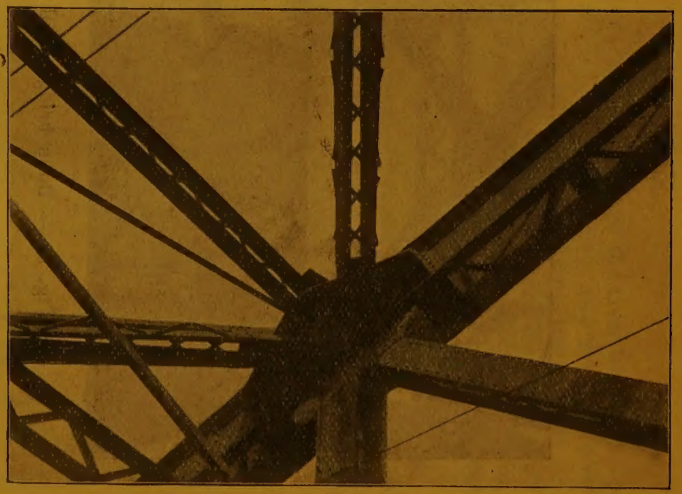


Fig. 9. — Dusseldorf bridge. Junction of windbracing members.

Figs. 10 and 11. — Dusseldorf bridge.

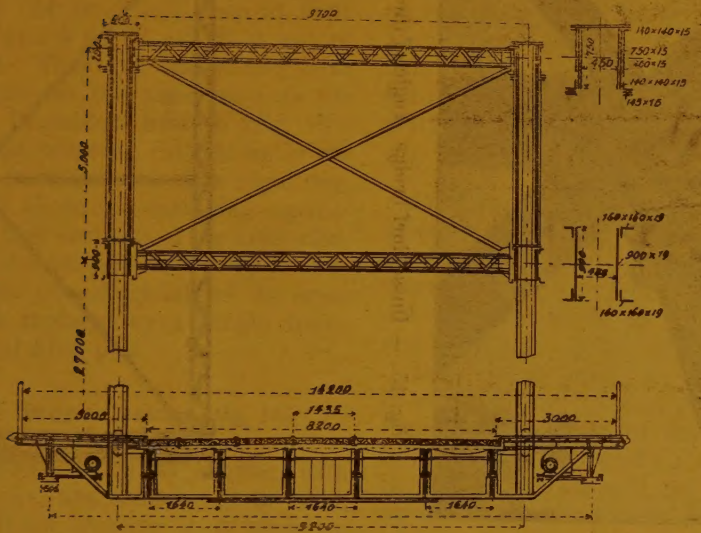


Fig. 10. — Cross section of the bridge with windbracing cross frame.

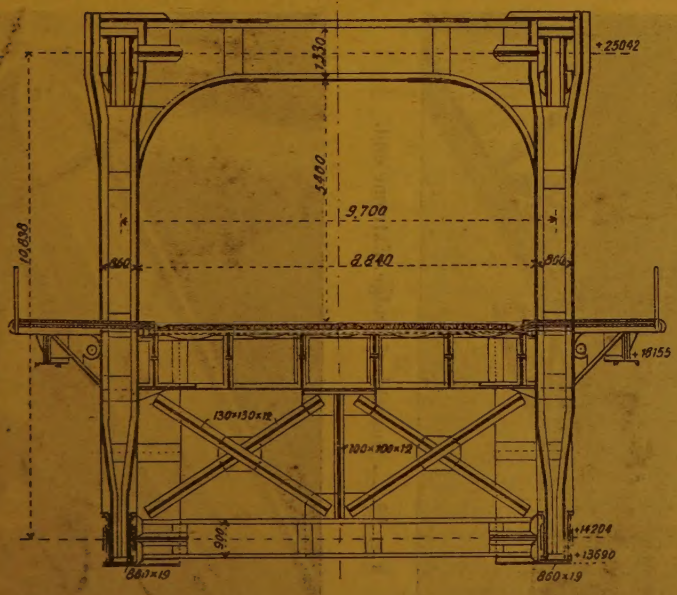


Fig. 11. — Cross section showing the end portal.

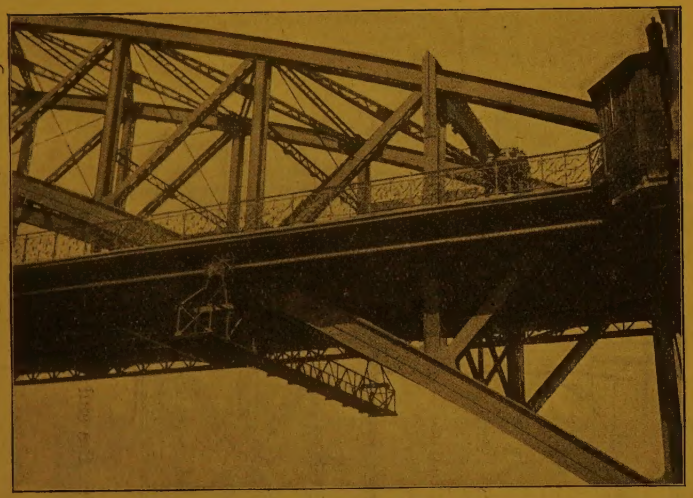


Fig. 12. — Dusseldorf bridge. Extreme end.

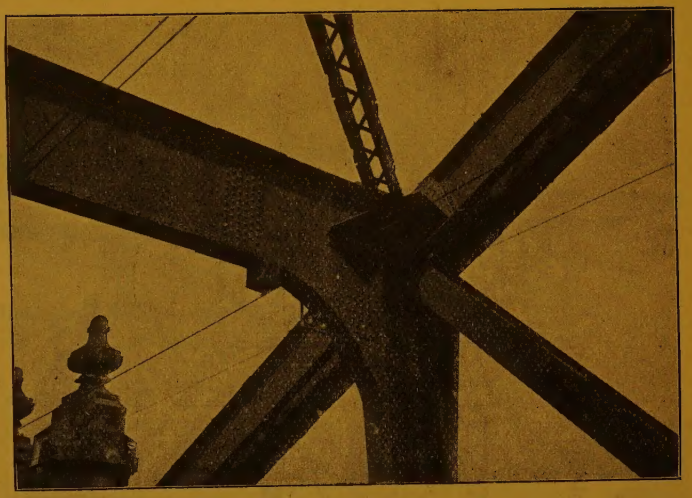


Fig. 13. — Dusseldorf bridge Angle of the portal.

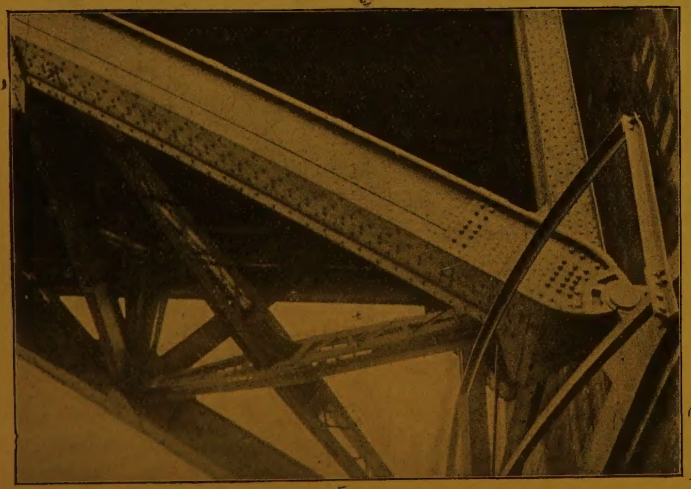


Fig. 14. — Dusseldorf bridge. Hinge joint at the springings.

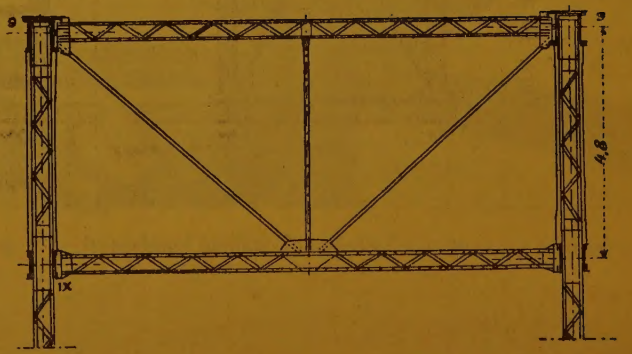


Fig. 15. — Magdebourg bridge Cross bracing of the arch booms or chords.

2 m. 35 (7 ft. 8 in.) rise. The arches at Magdebourg *without chord ties* are 10 m. 50 (34 ft. 4 in.) deep at their springing and 4 m. 80 (15 ft. 9 in.) at the crown. They are braced and have cross frames in the same way as the Bonn and Dusseldorf bridges (fig. 15). The bracing, however, extends *up to the first apex from the end.* The rigid portal is built above the springing consisting of the first verticals of the main ribs, with a rigid strut between the top booms.

The angle iron diagonals of the cross frames are replaced by a simple frame with central king post.

§ 2. — Worms bridge (fig. 16).

The railway bridge at Worms, with double tracks, was constructed in 1900. For the Rhine crossing it is made up of three successive spans, the central one having a length of 118 m. 30 (388 feet) and the side ones 107 m. 15 (351 ft. 6 in.). It is continued on the opposite side from Worms by a series of horizontal spans with 35 m. 25 (115 ft. 7 in.) openings and made of horizontal truss girders fixed under the roadway. These spans are composed of two independent superstructures each carrying a single track (fig. 17).

The large spans built over the Rhine carry double tracks, and the main girders are fixed with 9 m. (29 1/2 feet) between centres.

Main girders. — The main girders are formed of braced arch trusses with wide panels and curved top and bottom booms or chords. The platform is fixed above the springings (fig. 18) at the level of the second apex of the lower boom.

These arched trusses are connected between their ends by means of a horizontal tie fixed on a level with the platform and take up the horizontal thrusts, thus transforming the arch into a truss on two supports with vertical reactions. These trusses are braced together on the top between the upper members, and below between the horizontal ties at the platform level by means of bracing (fig. 19), which will be described later on.

Platform. — The platform, consisting of cross girders and rail bearers, is suspended from the soffit of the main trusses by means of verticals of double « T » section made up of a plate web and four angle irons (fig. 20).

The chief feature of the Worms bridge in comparison with similar structures is that the cross beams of the platform are hinged to the suspending verticals. In its turn the horizontal tie is supported by a shackle slung from the suspension pin which passes through the cross girder, and is supported sideways by simply butting against the latter.

Vibration and brake action. — The platform, which is free to move longitudinally relative to the horizontal ties and to the verticals, is fixed in the middle to the horizontal tie, and a brake stay (*Bremsverband*) transfers to the latter the longitudinal stresses due to adhesion and brake action. To counteract vibration, ordinary cross frames with horizontal and diagonal struts are fixed between the rail-bearers (fig. 20).

Windbracing. — The general scheme of the main framework comprises the main trusses with horizontal ties having an upper system of bracing which follows the neutral axis of the top boom, and a lower system of windbracing fixed at the level of the platform and extending between the second apex from each support following the line of the neutral axis of the lower boom (figs. 17 to 23).

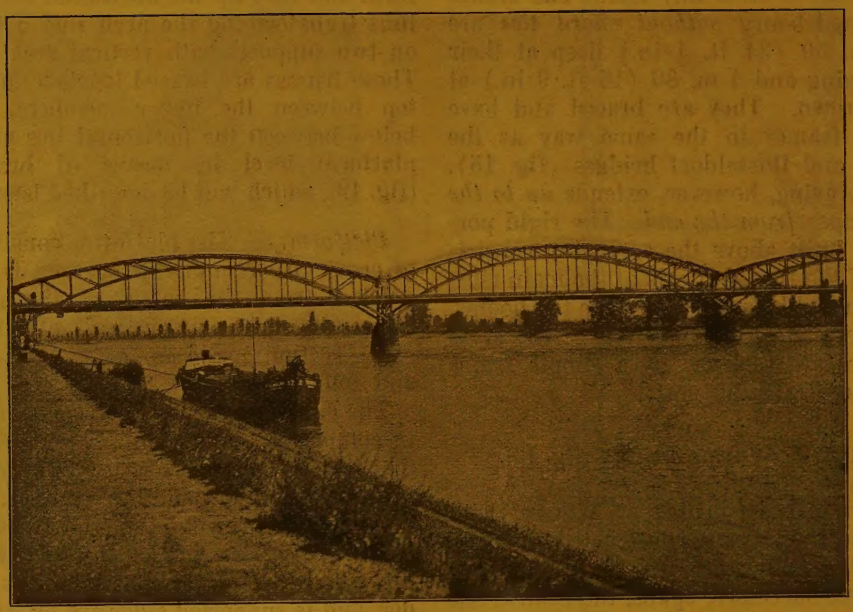


Fig. 16 — Worms bridge. General view.

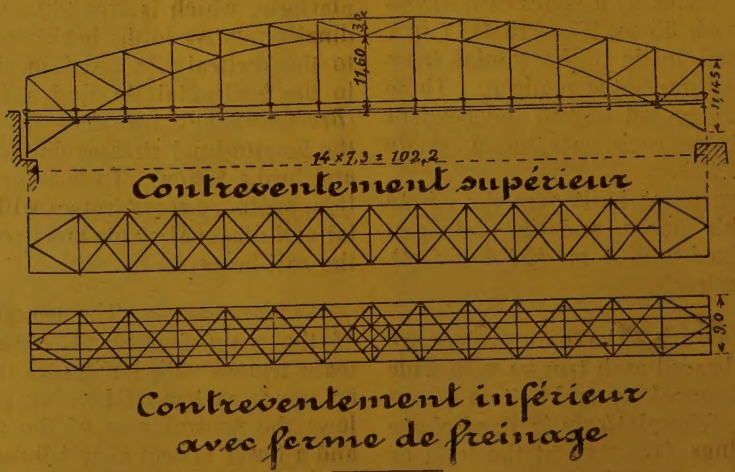


Fig. 17. — Worms bridge. Diagram of a side span.

Translation of French terms : Contreventement supérieur = Upper windbracing.
Contreventement inférieur avec ferme de freinage = Lower windbracing showing brake action framing.

Figs. 18 and 19. — Worms bridge.

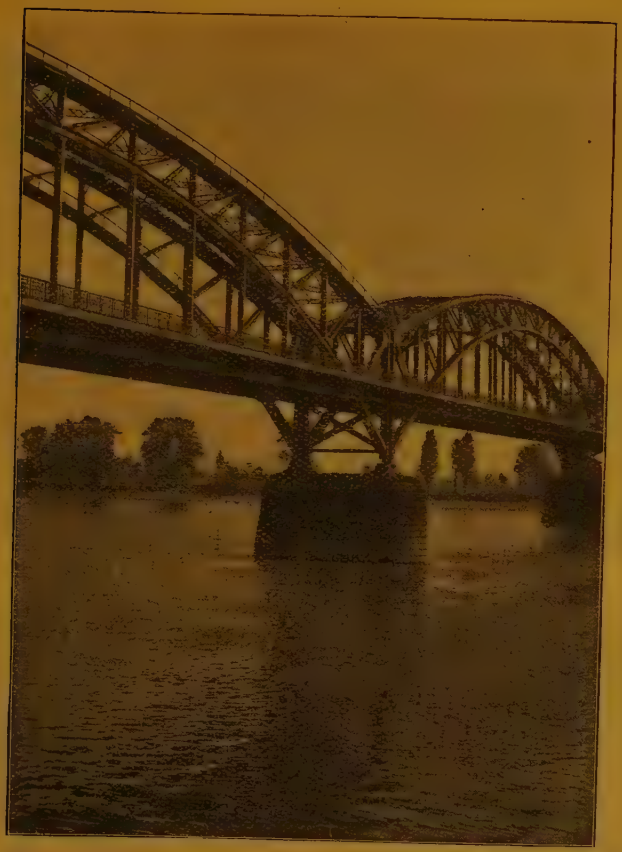


Fig. 18. — General view showing pier in river.

Fig. 19. — View showing horizontal tie connections.

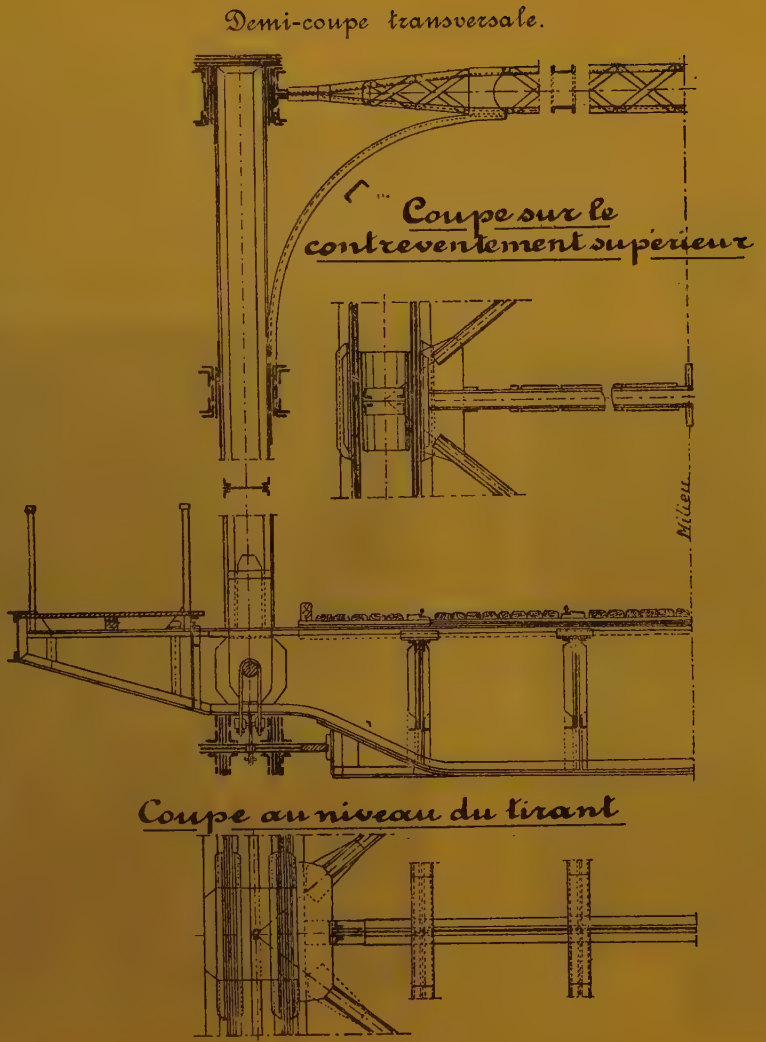


Fig. 20.

Translation of French terms : Demi-coupe transversale = Half cross section. — Coupe sur le contreventement supérieur = Section of the upper windbracing. — Coupe au niveau du tirant = Section at the level of the horizontal boom or tie.

Fig. 21.
General view of the upper windbracing.

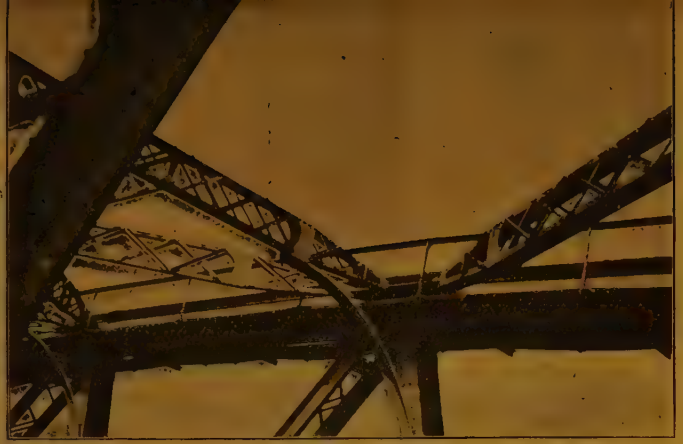


Fig. 22 — Worms bridge. Jointing of the apex in the upper windbracing.

Fig. 23. — Worms bridge. View of the end portal.

Fig. 24. — Worms bridge. Connections at an apex in the lower flange.

Figs. 22 to 24. — Worms bridge.

The top windbracing formed of diagonal and cross bracing struts, is hinged by means of plates to the top boom in the line of its neutral axis. The general arrangement, including the booms, forms a curved braced girder (fig. 21).

The extreme end verticals of the truss form the upper supports of a rigid portal transferring the transverse stresses on to the supports.

The diagonals consist of girders with channel flanges joined together by a double lattice composed of angle irons and flat bars. The ends are bent together whistle fashion so that the two channels grip the connecting plate which is fixed to the inner web of the boom by angle irons.

At the bend, the channels are stiffened by plates fastened on by means of four rivets.

The arrangement is completed by means of a longitudinal connecting girder placed along the axis of the curved girder. It is not easy to understand the function of this light girder, which is simply made up of an upper and lower angle iron reversed on either side as regards the symmetrical plane and joined together by a light and single lattice of flat bars (1).

In addition, the cross bracing struts are supported by light curved channels fixed to the verticals from which the platform is suspended. The photographs show all these details very clearly.

The lower windbracing fixed on a level with the platform of the bridge is composed of a lattice girder formed by the horizontal ties and intersecting diagonal bars with flexible connections to the horizontal ties.

The cross girders of the platform simply butt against the apices of this girder. In the centre, the truss to resist brake action is fastened to the horizontal ties and forms a rigid panel in the windbracing, ensuring the transfer of the longitudinal stresses to the supports of the bridge.

The end panels of the upper and lower windbracing are « K » braced instead of the usual diagonal form. This arrangement secures the transmission of stresses to the middle of the top and bottom cross struts of the rigid portals at the ends of the bridge (fig. 23).

Principle of the Worms bridge. — The jointed connections of the upper windbracing and the hinged joints of the cross beams to the suspension verticals realise what the Germans call « *die freischwebende Bahn* », *i. e.*, the almost complete independence of the main arch framework from the elastic distortions of the platform. These distortions are especially noticeable in structures with double tracks on account of the unequal loading.

As far as possible, this method of construction solves the principle of relative mobility between all parts of the framework (fig. 25).

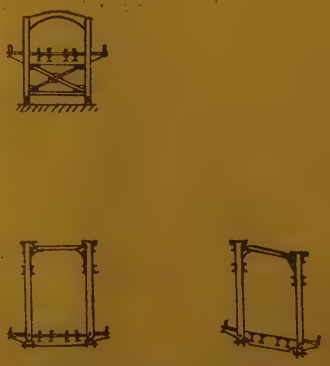


Fig. 25. — Worms bridge. Cross sections.

In bringing this short monography to

(1) This girder is evidently to stiffen the cross bracing. (*English Editor.*)

Fig. 26. — Connection at an apex in the lower flange.

Fig. 27. — Fixed arrangement.

Fig. 28. — Arrangement for cross expansion.

Figs. 26 to 28. — Worms bridge.

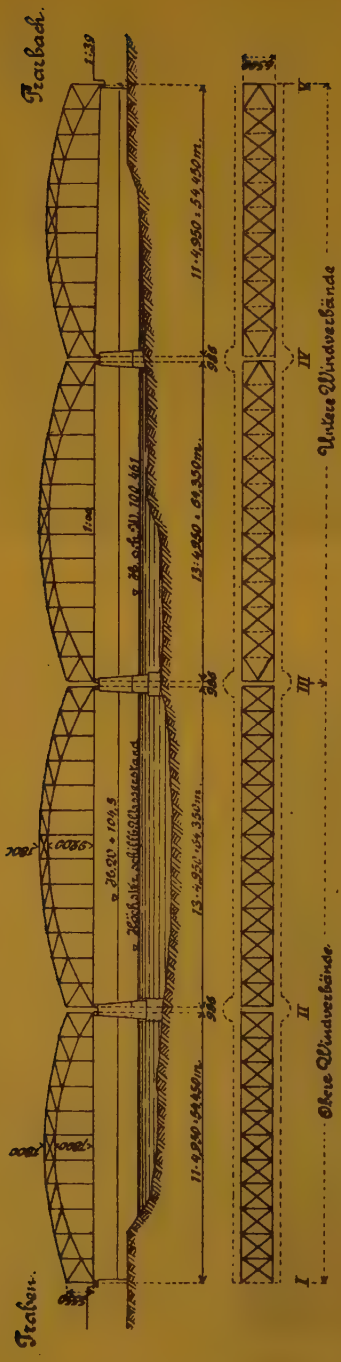


Fig. 29. — Trarbach-Traben bridge. General elevation.

Translation of German terms :
Höchster schiffb. Wasserstand = Highest water level. — Obere Windverbände = Upper windbracing.
Untere Windverbände = Lower windbracing.

a close, we would like to draw attention to the following points :

Members. — The webs of the box shaped double members are firmly bound together on the open side by means of a double lattice made up of diagonal flat bars, which are fastened at their extremities and at their intersection by one rivet only. Besides this strengthening arrangement, the webs are joined together by simple diaphragms (fig. 26) every second panel of the flat barred lattices.

The lower angle irons of the diaphragms are extended under the upper boom so as to carry a wooden gangway in order to allow of the inspection of the framework (figs. 27 and 28).

Supports. — The bearings allow for expansion, both longitudinally and transversely, and for this purpose, there is arranged at one corner of the bridge, a fixed support with spherical joint. At the other end of the same truss, a roller bearing is arranged to allow for longitudinal expansion. Under the other truss, placed crossways to the fixed support, a similar arrangement allows for transverse movement, whilst at the other end of this girder, the contrivance is made up of double roller bearings to allow for both longitudinal and transverse movement.

Foundations. — The pier foundations placed in the river were constructed by means of sunk caissons worked with compressed air, and the abutments on the river side by means of cofferdams.

Trarbach-Traben bridge over the Moselle (fig. 29). — The *highway bridge of Trarbach-Traben* over the Moselle, begun in 1897 and finished in 1899, was built before the railway bridge at

Figs. 30 and 31. — Trarbach-Traben bridge.

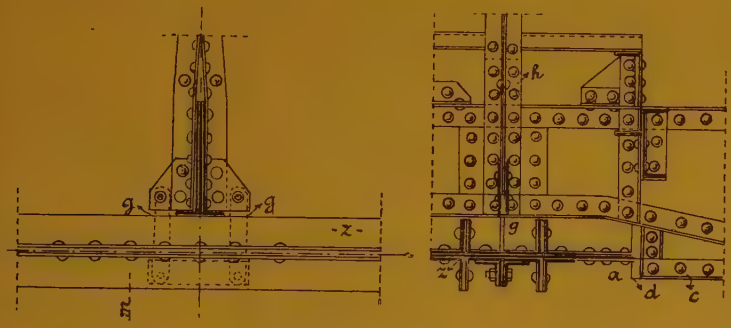


Fig. 30. — Suspension details of the horizontal boom or tie.

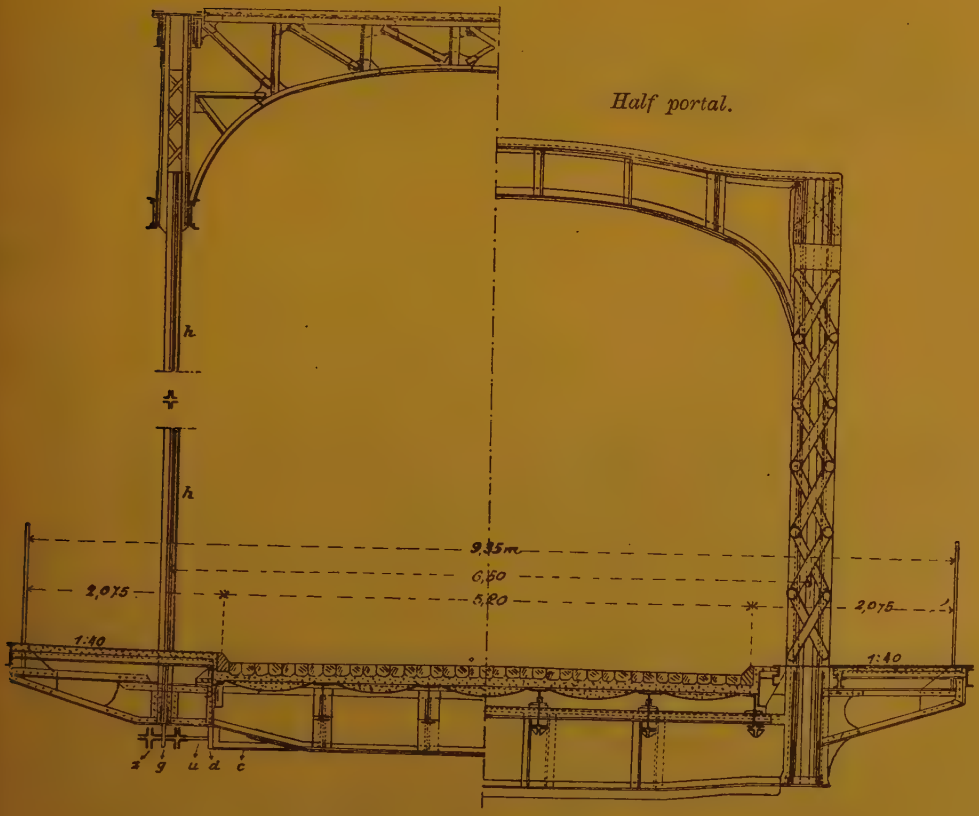


Fig. 31. — Half cross sections.

Worms, and on the same principle as the latter.

The horizontal tie (fig. 30) is simply hung to the cross girders by an extension of the truss verticals from which the platform is suspended and butts laterally by simple contact against these beams (fig. 31).

The suspension verticals embrace and are rivetted to the web of the cross girders. Their *flexibility*, however, is made as perfect as possible by the arrangement of their cross section, which is formed of four angle irons placed back to back fastened together in the form of a cross. The flexibility obtained by this construction allows the main girders to be independent of any distortion of the platform.

Another feature of this structure is the cross bracing of the upper chords by braced frames in the shape of spandrel braced arches (fig. 31).

§ 3. — Mayence railway bridge.

The new *Mayence railway bridge* (*Kaiserbrücke*), on the line from Mayence to

Fig. 32. — Mayence b

Wiesbaden, was put into service on the 1 May 1904, it is therefore of later construction than the Worms railway bridge, and contains some of the essential features of the latter (fig. 32).

Its general arrangement consists of two groups of large arched spans with wide panels separated by six parallel flange braced girder deck spans, the superstructures of which carry the railway. These spans are each 39 m. 20 (128 ft. 7 in.) long, and the length of the girders of the first group, consisting of three arched spans, are respectively 93 m. 80 (307 ft. 9 in.), 107 m. 20 (351 ft. 9 in.) and 107 m. 20 (351 ft. 9 in.). The two arches of the second group have spans 116 m. 80 (383 ft. 3 in.) each. The main girders, composed of braced arch trusses, have horizontal ties above the springings at the level of the second apex of the lower boom. The relationship of this structure to the Worms bridge is especially noticeable by the fastening of the horizontal ties, which are simply hung from the cross girders against which they butt (fig. 33).

Contrary to the construction of the Worms bridge, however, the cross sections of the verticals formed in a double

« T » (a web and four angle irons) are rivetted to the cross girders, but with a semi rigid connection without stiffening *gussets* (fig. 34).

The lower windbracing is constructed similarly to the Worms bridge by intersecting diagonal bars fastened to the horizontal ties which form the booms of the windbracing girder.

In the centre of the platform the horizontal ties are rigidly fixed to the middle cross girder, and as at Worms, a central bracing for brake action (*Bremsverband*) has been introduced to take the longitudinal stress in the flooring (fig. 35).

The *upper windbracing* is solely made up of diagonals with hinge jointed connections following the neutral line of the upper boom. The transverse struts in the Worms bridge, as well as the slender longitudinal girders connecting the diagonals of the windbracing and also the curved channel supports connected to the verticals from which the platform is suspended, have been discarded. The diagonals are still made up of « U » shaped members joined togeth-

g.

grammatic elevation.

er by a simple lattice and bent whistle like so as to grip the plates where they are fastened at their ends.

The windbracing finishes at the end portals in the angles with connections to plates fixed on the flanges of the upper booms of the arches (figs. 36 and 37).

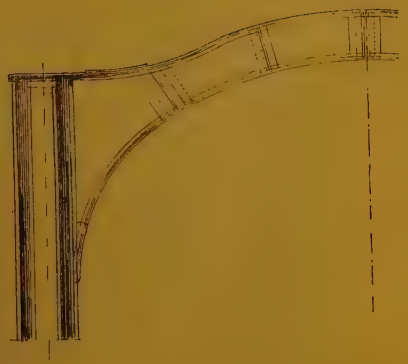
Only *longitudinal expansion* has been taken into consideration as far as the carrying arrangements are concerned, and the transverse contrivances for this purpose used on the Worms bridge are absent.

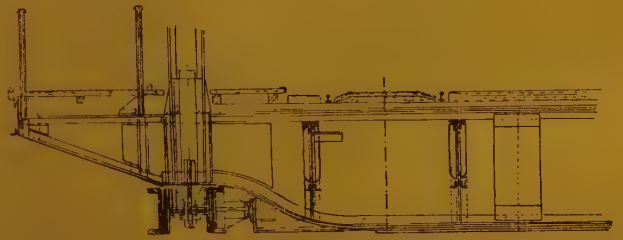
It remains to be mentioned, that as an original detail of construction, the box shape girders are stayed by means of a double lattice made of single flat bars with two « Us » extending the full length of the member. The bracing is completed at every second cross bar by means of solid diaphragms without outside covering plates.

§ 4. — Cologne railway bridge.

Süd Brücke railway bridge. — *The Süd Brücke railway bridge* at Cologne has double tracks and three spans, the central one of which has a length of 165 m. (541 ft. 4 in.), and the two side ones

Portal.





Half cross section.

Fig. 33

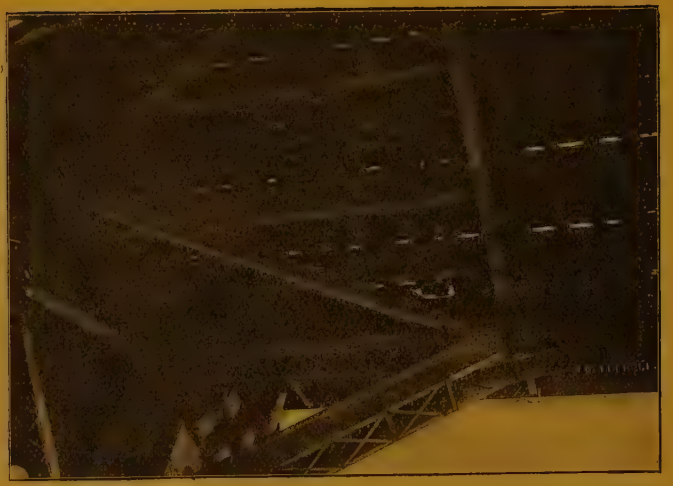


Fig. 34 — Lower windbracing and end of bracing jointing.

Fig. 35 — Upper windbracing.

Figs. 33 to 35. — Mayence bridge.

101 m. 50 (333 feet) each. The latter are supported by the projecting ends of the central span (figs 38 and 39).

General arrangement. — This structure, which in chronological order followed that of Mayence, was put into service at the beginning of 1910. The main girders, as in the latter, are still of the arched type with wide panels and horizontal ties. The principle of making these ties independent as regards the cross girders has been abandoned, and in this case they are fixed to the main girders. However, in order to ensure relative independent movement of the platform and the ties, this platform is divided up into a certain number of sections, each one of which is fitted with an independent bracing to counteract brake action (*Bremsverband*).

The connection of the verticals and cross girders is still made semi rigid, like at Mayence, without any large connecting gussets (fig. 40).

The top windbracing of the *Süd Brücke* has several interesting features.

As regards the side spans with diagonal bracing only terminating in the angles of the end portals, the designs are identical with those of the Mayence bridges (figs. 41 and 42).

The diagonals, which are made up of two « U » pieces joined together by means of a lattice formed of flat bars, are rigidly fastened to the top booms of the arches.

The central plane of the windbracing is arranged so as to follow the neutral axis of the upper booms. The end fastenings on the angles of the portals are flexible, and the « Us » are closed up so as to grip the flexible connecting plate in the angles of the portals (figs. 43 and 44).

The side spans have only a curved girder for windbracing, as shown between the upper booms.

The central span is of too great a length for this method to be followed. In order therefore to make a suitable bracing arrangement, cross struts have been added to the eight middle panels of the same cross section as the diagonals and cross frames between the upper and lower booms of the arches (fig. 45).

The members of these frames are made up very simply in pairs of « U » irons connected by plates (fig. 46).

The bracing of the box shaped members consists of single angles with uprights. It is still further strengthened at the third and the two thirds of its length by means of solid diaphragms.

Hohenzollern Brücke railway bridge. — This bridge, which was constructed after the completion of the *Süd Brücke*, is composed of two railway bridges with double tracks and one road bridge alongside.

The structures are made up of three spans, the two side ones being 118 m. 80 and 122 m. 56 (389 ft. 9 1/2 in. and 402 feet) long, and the central span being 167 m. 75 (550 ft. 5 in.) long (fig. 47).

The main girders are again formed of braced arch trusses with wide panels and horizontal ties, the latter this time being fixed on a level with the springings.

On examining the cross section of the railway bridges (fig. 48), we perceive that the connection of the horizontal tie, cross girder, and suspending vertical, is perfectly rigid with large triangular strengthening gussets fixed between the vertical and the cross girder.

The upper windbracing of the side spans is made up of diagonals without cross frames, with flexible joints (fig. 49)

Fig. 36. — View of portal and ends of upper windbracing.

Fig. 37. — Angles of the end portals.

Figs. 36 and 37. — Mayence bridge.

Fig. 39 — Cologne Süd Brücke railway bridge. — Pier support.

Diagrammatic elevation.

Upper windbracing.

Flooring.

Fig. 38. — Cologne Süd Brücke railway bridge.

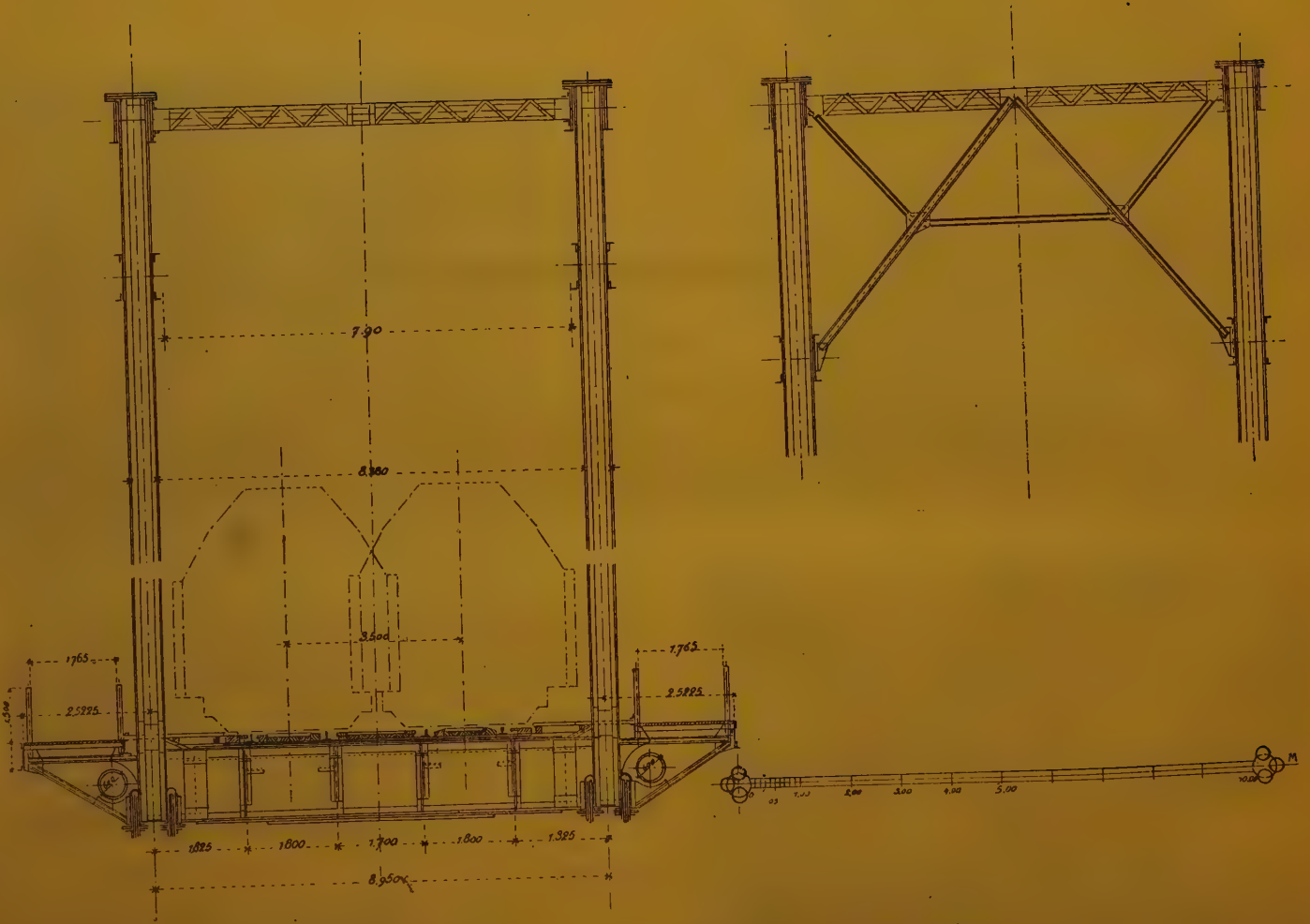


Fig. 40. — Cologne Süd Brücke railway bridge. — Cross sections.

Fig. 41. — Side spans.
General view of the windbracing.

Fig. 42. — Connections of the upper windbracing.

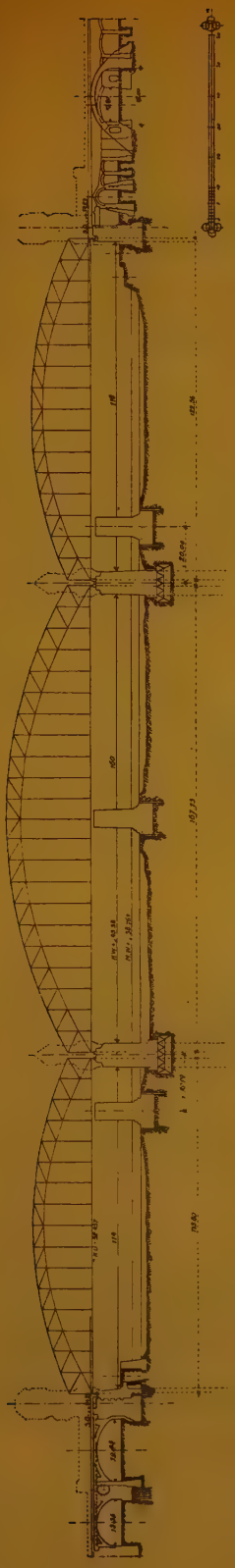
Fig. 43. — Upper windbracing. Intersection of the diagonals.

Figs. 41 to 43. — Cologne Süd Brücke.

Fig. 44. — End portal. Windbracing connections.

Fig. 45. — General view of windbracings. Central span.

Fig. 46. — Connections at an apex in the lower boom or chord.



Diagrammatic elevation.

Fig. 47 — Cologne Hohenzollern Brücke.

to the flange of the upper boom. At the extreme ends the curved windbracing girder terminates in the angles of the portals, the diagonals being attached to the flange plate of the boom (fig. 50).

These diagonals consist of two « U » pieces with double lattice flat bar bracing.

A feature in the windbracing (fig. 51) is the addition in the last panel of a king-post between the intersection of the diagonal and the middle of the portal.

We should point out too, that the end portals are braced (fig. 52).

In the *central span,* two upper windbracing systems have been provided (see cross section), one being fastened to the flange of the upper boom, and the other in the neutral axis of the lower one, Both consist of diagonals without cross frames as in the side spans.

Evidently the windbracing between the lower booms could not be continued for the whole length of the structure. In the third bay from the springing, it is connected with the upper booms by a lozenge shaped panel (fig. 53) fixed in the plane of the corresponding diagonals of the main trusses.

The particular care which has been given to obtain *hinged jointing for the windbracing of the lower booms* should be particularly noticed. The plate connecting the diagonals is fixed to the web of the boom by two angle pieces with a gap between.

The bracing of the box shaped booms (fig. 54) consists of a double lattice of flat bars with solid diaphragms every second bay.

§ 5. — **Hamm bridge.**

The Hamm bridge, which is situated on the line from Neuss to Dusseldorf, is composed of two large railway bridges

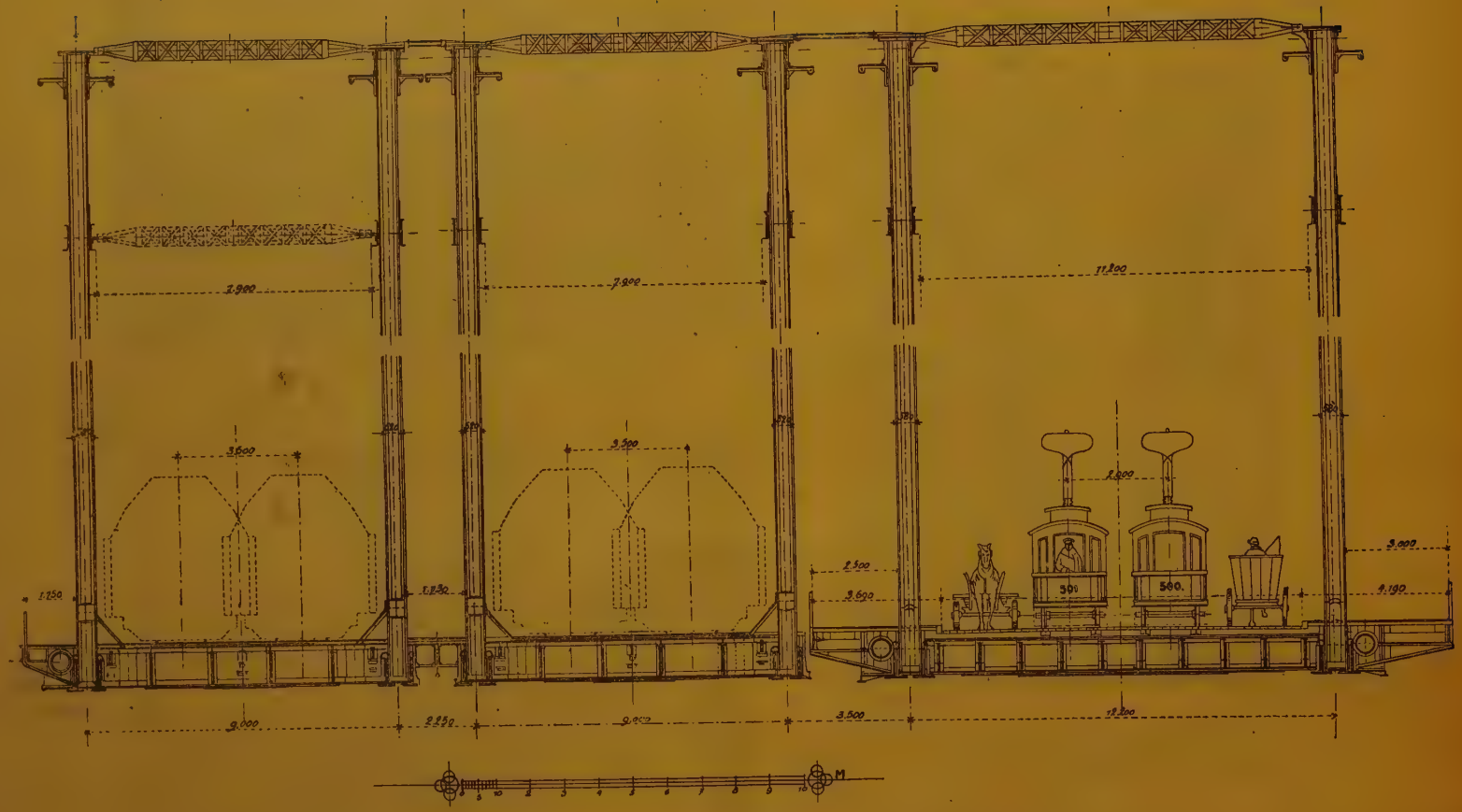


Fig. 48. — Cologne Hohenzollern Brücke. — Cross sections.

Fig. 49. — View of the upper windbracing of the side spans.

Fig. 50. — Connections at an apex in the upper windbracing.

Fig. 51. — End portal showing windbracing connections.

Figs. 49 to 51. — Cologne Hohenzollern Brücke.

Fig. 52. — Angles of the end portals.

Fig. 53. — Central span. Upper windbracing. Panel of cross framing.

Fig 54. — Apex of the lower chord.

Figs. 52 to 54. — Cologne Hohenzollern Brücke.

Fig. 55. — General view.

Fig. 56.
Support of the framing on a pier in the river.

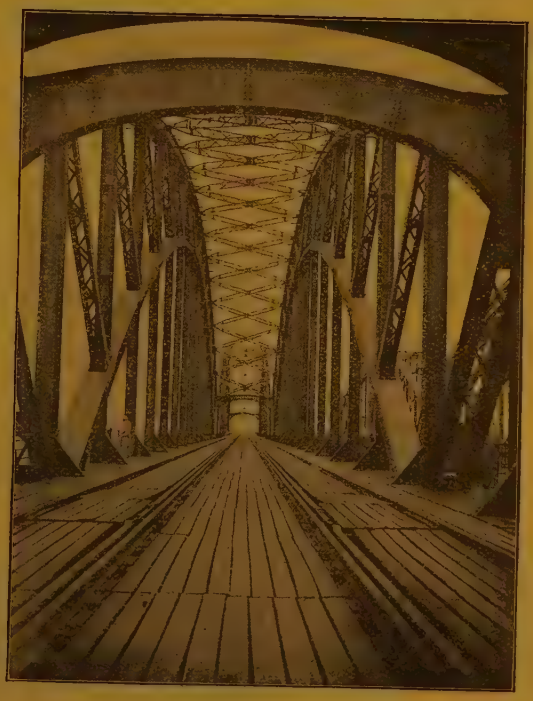


Fig. 57.
View showing upper windbracing.

Figs. 55 to 57. — Hamm bridge.

with double parallel tracks. Each consists of four spans of about 107 m. (351 feet) long over the Rhine (fig. 55).

The general arrangement of the main girders is similar to that of the Worms bridge. They are braced arch trusses with wide panels and sixteen bays with two booms and a horizontal tie at the level of the second apex of the lower boom (fig. 56). The platform is suspended from the main girders by means of double « T » verticals (web and angle irons).

With the Hamm bridge, like the *Hohenzollern Brücke*, the relative independence of the platform in relation to the bracing in general has completely disappeared. The cross girders of the platform are rivetted by means of large gusset connections to the suspension verticals, and the latter in turn being rivetted to the horizontal ties. The connection of cross beams, horizontal tie and vertical is quite rigid (fig. 57).

The upper windbracing consists of a curved girder with diagonal bracing attached by flexible connecting plates to the flanges of the upper booms (fig. 58).

The windbracing at the end bays is also fixed to the flange of the boom in the angles formed by the portals with the main girders (fig. 59).

As in the preceding bridges, the end portals form rigid windbracing supports, transferring the side stresses, due to wind, on to the bearings.

The windbracing diagonals consist of « U » pieces with wings outside and stiffened by plates at their intersection, one of the « U » pieces being cut away for the purpose.

These « U » pieces are braced by two simple lattice angle irons alternating on the two wings, and are bent together at the ends so as to grip the flexible connecting plates on the flanges of the booms.

The bearings are rigidly fixed on one side of the pier, and on the other, are movable, this being the only means by which the bridge can expand longitudinally (fig. 60).

An interesting feature in the details is that the double web of booms are stiffened by means of a single lattice with « U » verticals of light section. Diaphragms have also been fixed at the ends as well as at two intermediate points.

The end connections are further improved by two « U » cleats of large section.

§ 6. — Rudesheim, Neuwied Engers and Remagen railway bridges

These three railway bridges, with double tracks, are of quite recent construction, and were entirely made or finished during the war. With the exception of a few details and the length of their spans, they are almost identical from a technical point of view.

The Rudesheim bridge (*Kempten*) has two large arched spans each 169 m. 40 (555 ft. 9 in.) long, and separated by three straight girder spans respectively 92 m. 55, 94 m. 20 and 92 m. 55 (303 ft. 8 in., 309 feet and 303 ft. 8 in.) long, approached at each end by means of a parallel flange open web braced girder 84 m. 70 (278 feet) long (figs. 61 and 62).

The Remagen bridge has a central arched span 156 m. 20 (512 ft. 6 in.) long, with a parallel flange open web braced girder span at each end 84 m. 60 (277 ft. 7 in.) long.

The Neuwied bridge (*Engers*) has a central arched span 188 m. (617 feet) long with two parallel flange open web braced girder spans at one end 84 m. 60

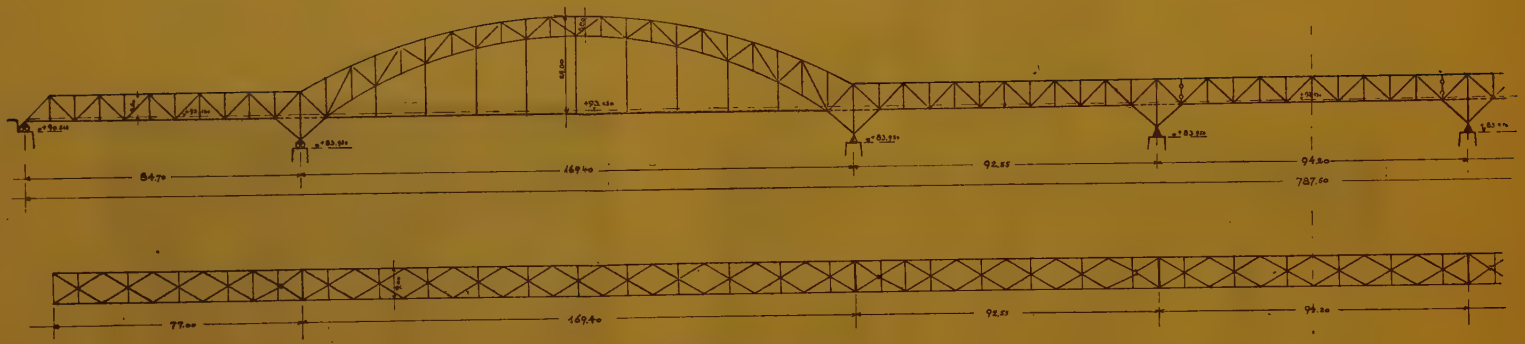
Fig. 58. — Angles of the portals.

Fig. 59 — End portal.

Fig. 60. — Supports on an intermediate pier.

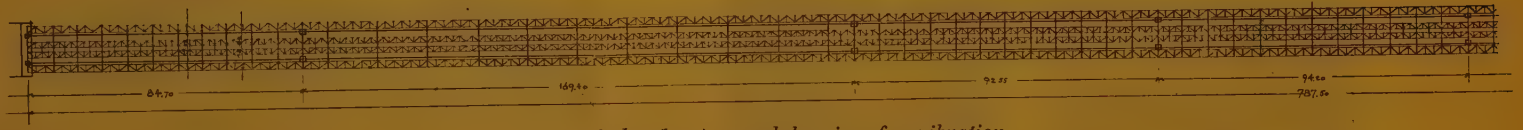
Figs 58 to 60. — Hamm bridge.

Part elevation of the main girders.



Upper windbracing.

Lower windbracing.



Details of the flooring and bracing for vibration.

Fig. 61. — Rüdesheim railway bridge.

(277 ft. 7 in.) long, and one at the other with an additional platform 75 m. 20 (246 ft. 9 in.) long (figs. 64 and 65).

The general characteristic of these arches is, like in the Cologne *Süd Brücke*, having overhanging ends which carry the side spans by means of swinging supports (figs. 66 to 68).

The more recent bridges of Neuwied and Remagen are built in open web braced (N type of girder) with verticals from which the platform is suspended in a line with all the verticals of the girders.

The Rudesheim bridge is made up of a triangulation with successive diagonals

Fig. 62. — Rüdesheim bridge. General view

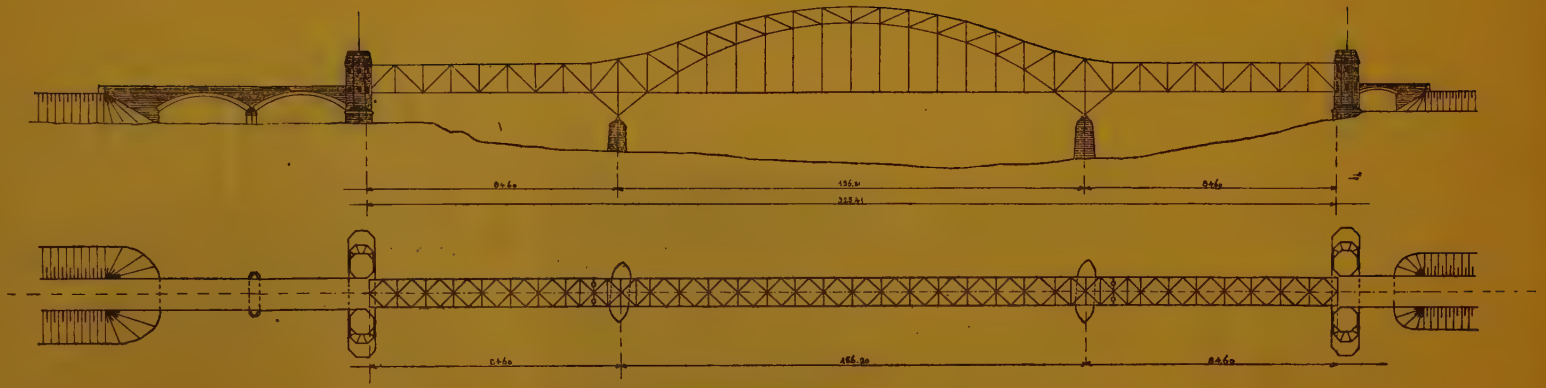
fixed in opposite directions, German fashion (*Strebenfachwerk*), with suspension verticals every second panel. The general arrangement of the Rudesheim bridge is perhaps more pleasing to the eye, but the design of the Remagen and Neuwied arches is certainly more logical (fig. 69).

The main girders are made up, as might be expected, of box shaped members. The open side of the latter is braced by a single lattice with verticals and diagonals alternating. The lattice is made up of flat bar to which an angle iron is rivetted with its vertical wing fixed towards the interior of the box girder (fig. 70).

The webs of the box girders are also stayed by solid diaphragms with external plates. These plates are rivetted to the angles at the edge by two or three rivets, according as the member is in tension or compression (figs. 71 to 73).

In cross section, the junction of the cross girder, horizontal tie and suspension vertical is entirely rigid, large

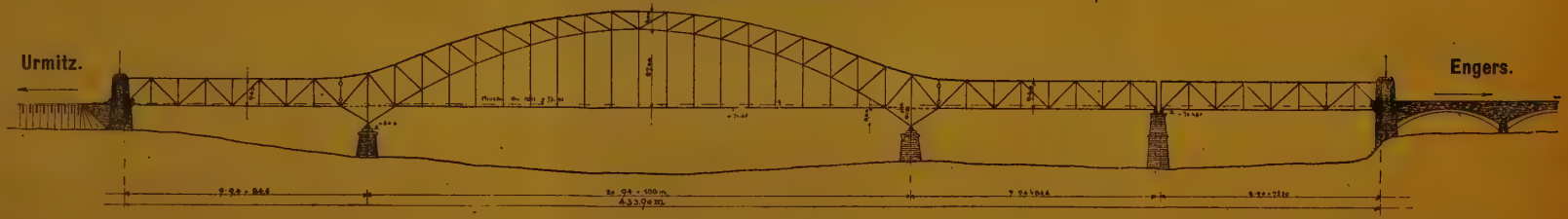
Diagrammatic elevation.



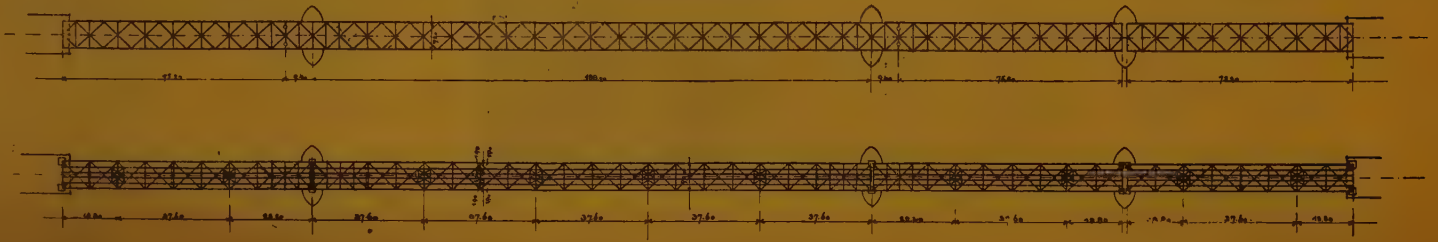
Upper windbracing.

Fig. 63. — Remagen railway bridge

Diagrammatic elevation.



Upper windbracing.



Flooring.

Fig. 65. — Neuwied bridge.
General view.

Fig. 66. — Rüdesheim bridge.
Support of the side spans on overhanging end of central arched span.

Fig. 67. — Neuwied bridge.

Support of the end spans on the arched truss.

Fig. 68. — Rüdesheim bridge.

Support of the end spans on the arched t

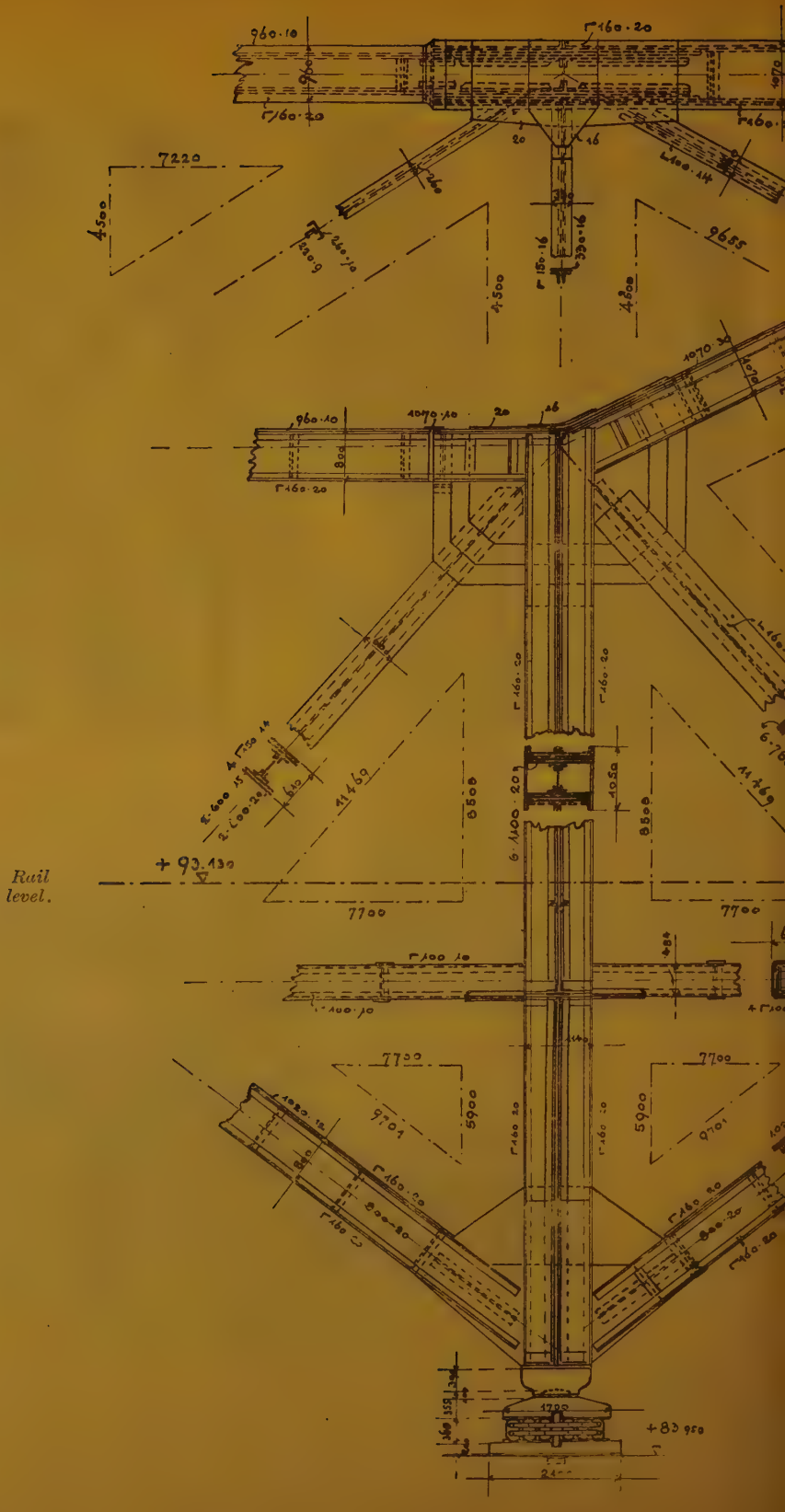
Fig. 69. — Neuwied bridge.

Portal at end of the central arched span.

Fig. 70. — Rüdesheim bridge.
Details of the truss members.

Fig. 72. — Neuwied bridge.
Details of the lattice.

Fig. 71. — Rüdesheim bridge. Straight spans.
Details of the truss members and windbracing.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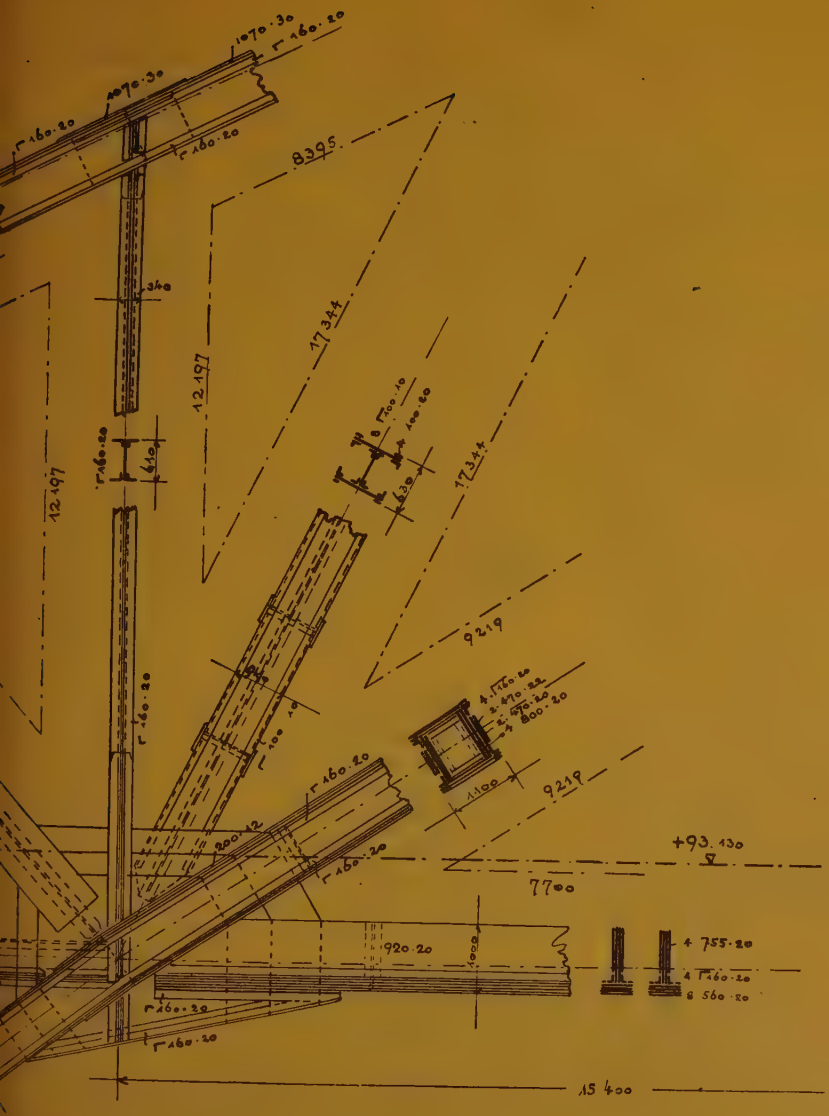


Fig. 73. — Rüdesheim railway bridge. Details.

triangular gussets being used to strengthen the connection of the vertical and cross girder (fig. 74).

The flooring is made up of cross girders and longitudinal rail bearers, with ordinary bracing for vibration and cross bracing between the latter.

About every fourth bay, the flooring is made rigid to resist brake action and transfer the longitudinal stresses on the road to the horizontal ties (fig. 75).

In these sections, the expansion taking place between rail bearer and cross stays is provided for by means of a new arrangement in the form of a *toothed roller*, the supporting plate being transformed into a rack.

The reason for this arrangement is probably to limit any movement of the bearing, at the same time making its action certain.

The *lower windbracing* takes the form of a girder with flat bar cross bracing, the horizontal ties acting as flanges and the cross beams as verticals (fig. 76).

The *upper windbracing* is single and rests on the flanges of the upper booms. It is formed of diagonals, the apices of the curved girder so formed being situated in the middle of the panels (fig. 77).

The diagonals which are made up of two ordinary « U » irons, the web of the horizontal one being rivetted to the wing of the vertical « U », are fastened to plates rivetted on to the upper flange (fig. 78).

The *feature of these three structures*, beyond the ordinary windbracing, is the rigid transverse bracing by means of portals in solid plating in line with each vertical strengthened by the top and bottom booms of the main girders and a supplementary strut between the upper members (fig. 79).

To the right of the *suspension panel* of the side spans of the arch, the upper windbracing terminates herring bone fashion, and is rigidly connected on one side, and hinged on the other (fig. 80).

The *swinging support* of the lateral spans on the arch is made up of a simple connecting rod in section, finishing off at the ends in ball and socket joints (fig. 81).

As regards the Rüdesheim bridge, we should also point out that in the three straight intermediate spans situated between the large arched spans, the middle one is supported on projecting ends of the side spans carried beyond the pier. The side spans in a similar manner being carried on projecting ends of the arched span.

§ 7. — **Baerl bridge.**

The *Baerl bridge*, on the Hohenbudberg line to Oberhausen, is of the ordinary truss type with horizontal bottom and parabolic top booms (fig. 82).

Built in 1910-1912, to the designs of Engineer Schaper, known by his treatise on metal bridges, it has three large spans over the river, the two end ones being 106 m. 08 (348 feet) long, and the central one 186 m. (610 ft. 3 in.), with approaches of lesser importance of parallel flanged deck spans which carry the roadway.

It is designed after the classical type known in Germany as *Strebenfachwerk*, the diagonals of the girder being in tension and compression alternately (figs. 83 and 84).

A feature of the central span with secondary framing is the horizontal ties along the central apices of the main trusses. These ties, which are very light, are simply to brace the apices referred

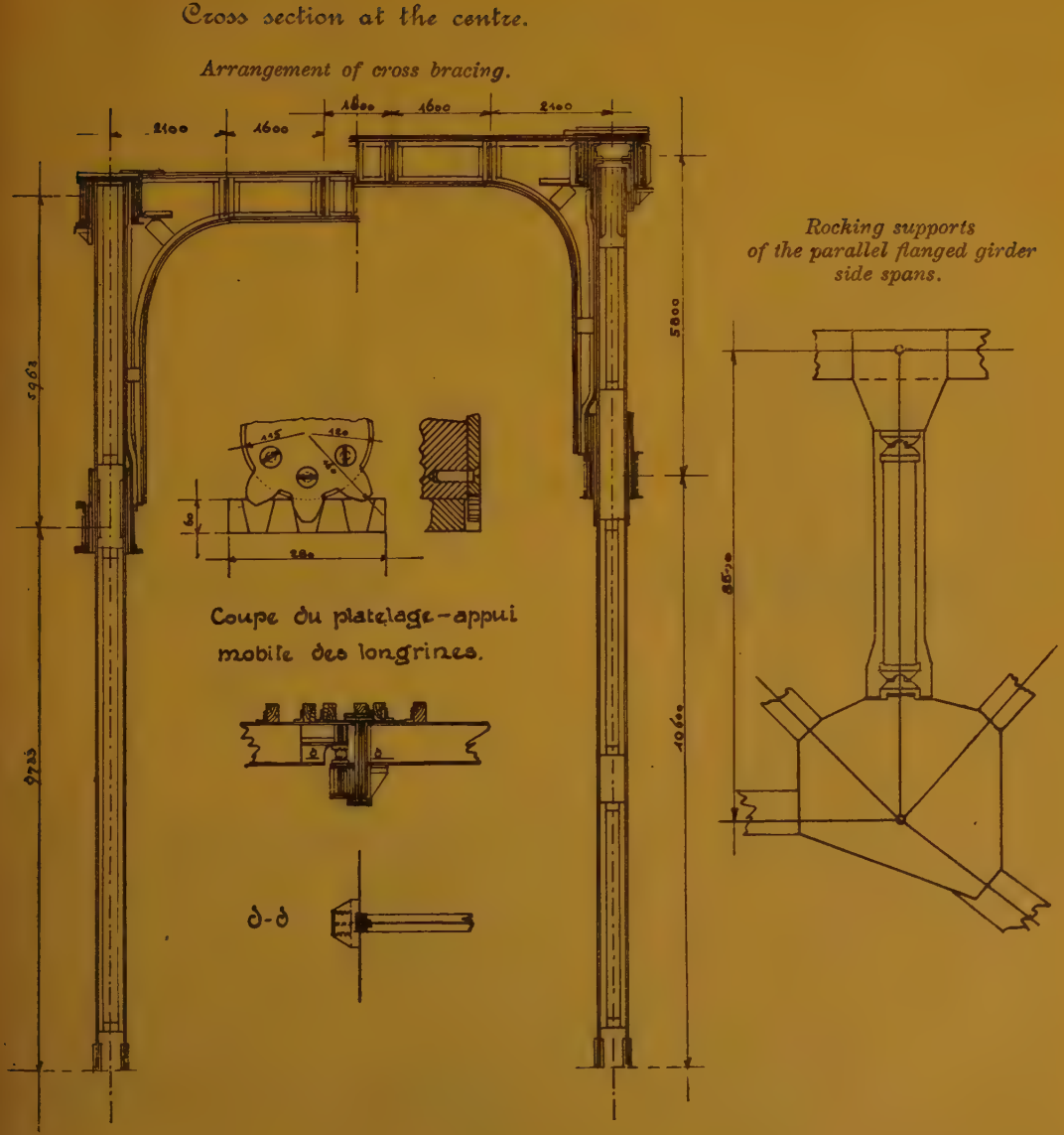
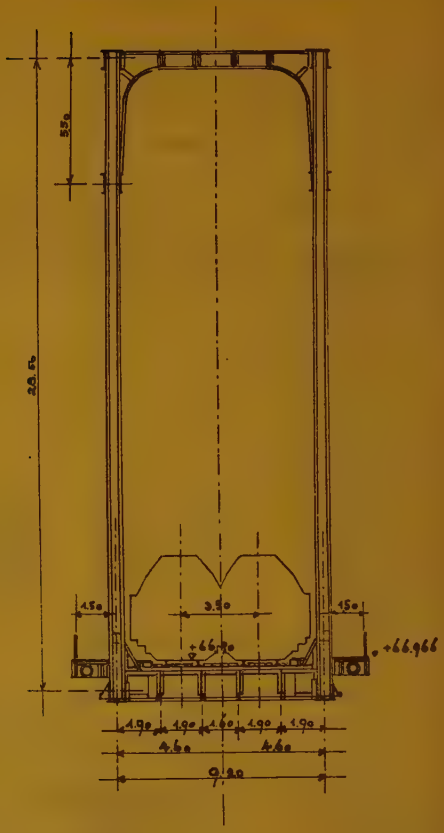


Fig. 75. — Rüdesheim railway bridge.

Translation of French terms :

Coupe du platelage — appui mobile des longrines = Cross section of flooring -- movable bearings of rail bearers.

at the end of the arched span.



Cross section
at end supports.

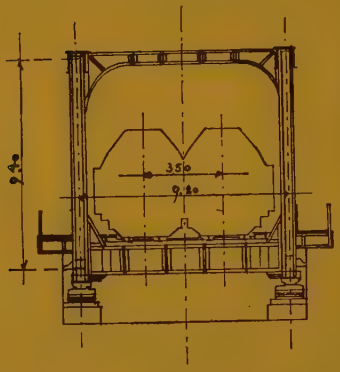
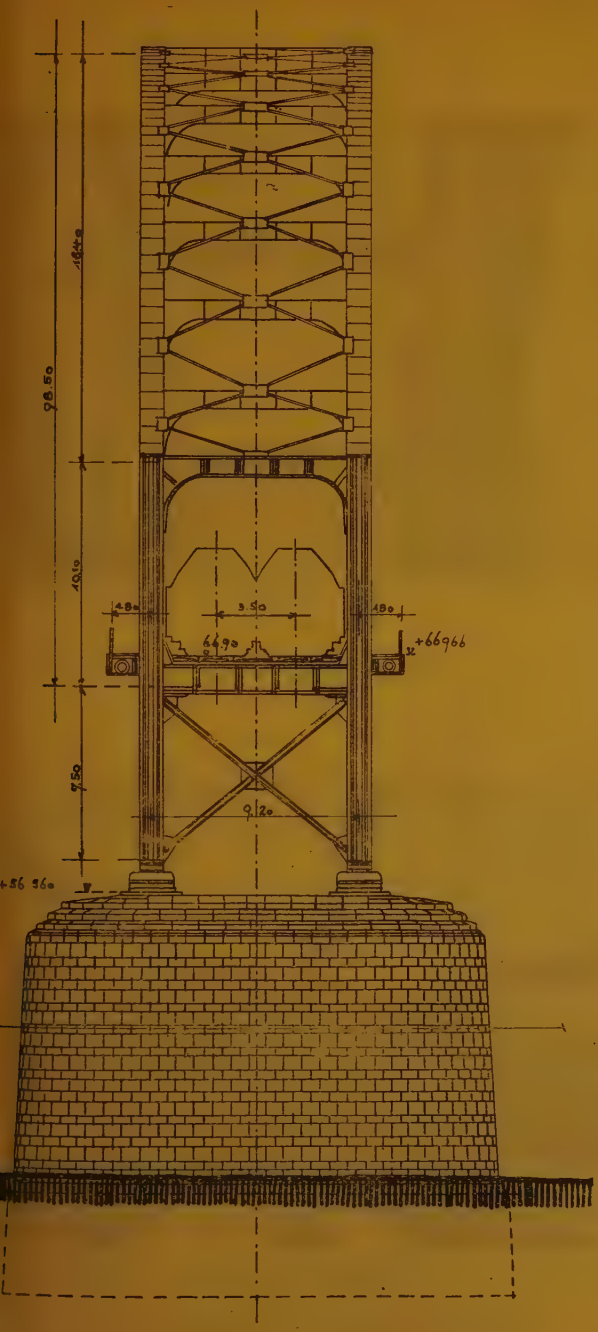
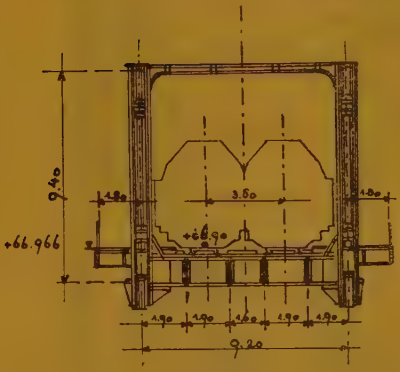


Fig. 74.

on the piers



Cross section
at hinged joints.



railway bridge.

Fig. 76. — Neuwied bridge.
General view of upper windbracing.

Fig. 77. — Neuwied bridge.
Upper windbracing.

Fig. 78. — Rüdesheim bridge.
Details of upper windbracing.

to and prevent them buckling longitudinally (fig. 85).

The top windbracing consists of diagonal curved girders following the flanges of the upper booms (fig. 86).

The verticals forming the cross struts are light open braced girders, and the diagonals, which are also very light, are connected together by plates at their intersection (fig. 87).

The whole arrangement is completed by means of a longitudinal beam connecting the intersection of the diagonals in the central plane of the floor (figs. 88 and 89).

An interesting point in the Baerl bridge is the arrangement for inspecting the top members by means of a trolley running on a rack (fig. 90).

One of these racks is suspended from the windbracing, and the others are fixed to the boom (fig. 91).

It is rather curious that with this structure the usual method of building the Rhine railway bridges with framed arches with wide panels has been departed from. A technical reason may be found in its much greater stiffness transversely, which from this point of view is superior to arched bridges with long flexible verticals. In addition, independent spans have been adopted, the cantilever method not being sufficiently economical as regards material.

§ 8. — Wesel and Hochfeld bridges

The *Wesel railway bridge* is the last one over the Rhine before reaching the Dutch frontier. The *Hochfeld bridge*, against which an attempt to damage it was made in July 1923, is situated on the Crefeld to Duisburg line. These structures are old and hardly worth mentioning.

We might point out that the German Administration was getting out designs for a *new railway bridge* to be joined up *to the present one at Hochfeld.*

The execution of this has, however, been stopped for the present, though the piles had already been driven into the river bed. It would have consisted of a large span over the river 187 m. (613 1/2 feet) long, with lattice arches and wide panels. It is not possible, however, to give further details concerning it.

II. — GENERAL REMARKS.

§ 1. — Main girders.

In all these structures, of which we have given a short description, the main girder is an open braced arch with wide panels, the height at the springings being greater than at the crown. This height at the springings is sufficiently great to permit the formation of end portals which has given to this type of girder, peculiar to Germany, the name of *Portalbogen.*

In the *Bonn and Dusseldorf road bridges,* which inaugurated this type of arch over the Rhine, the springings on the piers are hinged, the arch acting simply in a normal manner and thrusting against the pier supports. The horizontal thrust from the central span being equilibrated by the thrust from the smaller span side arches placed entirely below the roadway.

In all succeeding structures, a great improvement was effected in transform-

ing the arch into an equilibrated girder by the addition of a horizontal boom, forming a tie to take the thrust of the curved members and extending under the platform to points near the springings.

In the *Worms, Mayence, Cologne* (*Süd Brücke*) and *Hamm* (*Neuss*) *bridges*, the horizontal tie is situated above the abut-

Fig. 79. — Rocking support.

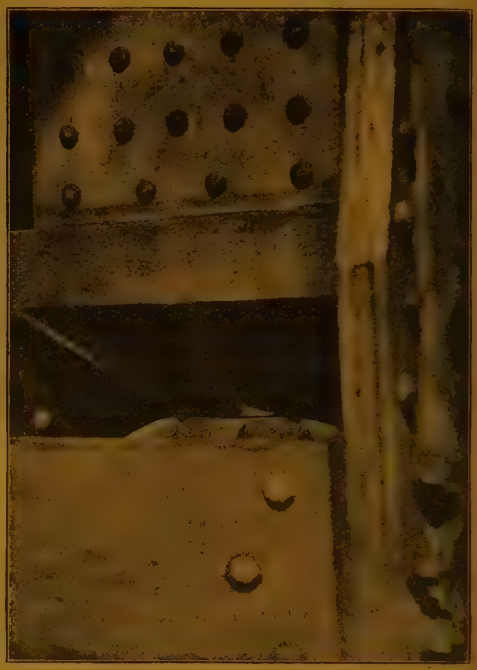


Fig. 81 — Details of rocking supports.

Figs. 79 and 81. — Rüdesheim bridge.

ments on a level with the second apex of the lower chord. The portions of the latter dipping under the platform to the bearings on the piers form metallic beaks or corbels.

In the *Hohenzollern Brücke at Cologne*, the horizontal ties are on a level with the abutments. This arrangement may be provided for exceptional floods or to take advantage of the maximum headway available under the side spans (provided with towing paths).

Apart from these arrangements, the junction of the horizontal tie is identical with that of the Worms bridge, etc.

In the structures we are considering, with large spans, the first object to attain is the best arrangement of cross bracing the main girders and reduce the height of the framework above rail level. The latter arrangement ensures the least movement in the framework, a desirable object in railway bridges.

The consecutive platforms of the

Worms, Mayence, Hamm bridges and *Hohenzollern Brücke* are independent of one another. In the three first mentioned, the consecutive arches have each a span of 100 m. (328 feet), and the position of the piers in the river is arranged to suit local conditions.

In the *Süd Brücke at Cologne* we have

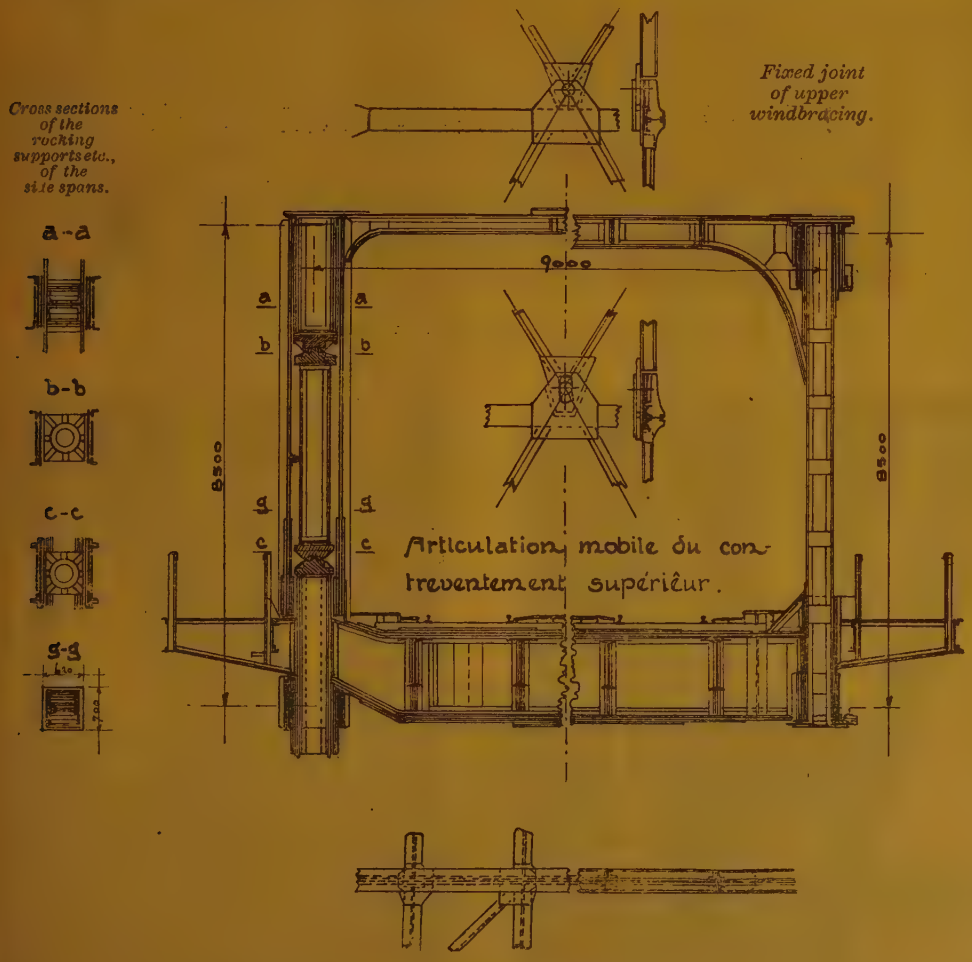


Fig. 80. — Rüdesheim railway bridge.

Translation of French terms : Articulation mobile du contreventement supérieur = Hinged joint of upper windbracing.

for the first time girders with projecting ends supporting one end of the side spans. The local conditions are about the same as those of the *Hohenzollern Brücke*, having a central span of 165 m. (541 1/2 feet), and two side spans 101 m. 50 (333 feet) long (*Hohenzollern* : central span 167 m. 75 (550 1/2 feet)

Fig. 82. — Partial elevation.

Fig 83. — Lower apex detail.

Fig. 84. — Lower apex detail.

Figs. 82 to 84. — Baerl bridge.

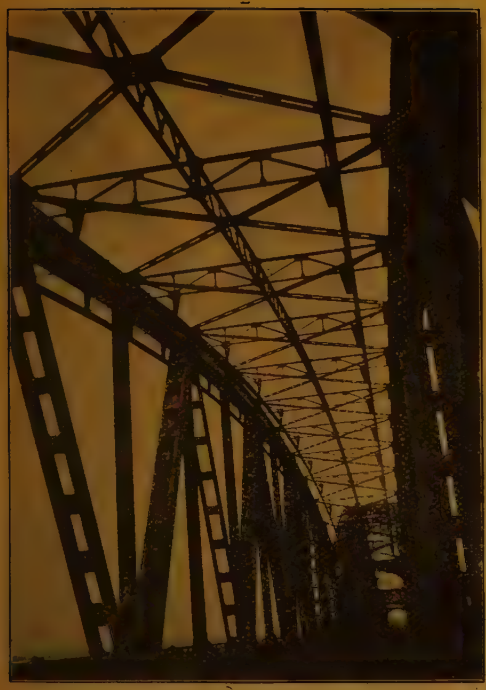


Fig. 85. — General view
of the windbracing of the side spans.

Fig. 86. — General view
of the windbracing of the central span.

Fig. 87. — Intermediate connection of the diagonals with the
longitudinal connecting girders.

Figs. 85 to 87. — Baerl bridge.

Fig. 88.
Angles of the end portals.

Fig. 89.
Lower connection of the end portals.

Fig. 90. — Inspection trolley of the upper member.

Figs. 88 to 90. — Baerl bridge.

and side spans 118 m. 80 (390 feet).

It is indisputable, that from a technical point of view, the design of the *Süd Brücke* is an improvement when local conditions allow of it being adopted. The end spans assist in a marked degree to lighten the strain on the central arch, The only objection to this arrangement is the difficulty of arranging the supports on the projecting ends.

Fig. 91. — Baerl bridge.
Upper member with rack arrangement.

This innovation in the *Süd Brücke* is also to be found in the three last bridges constructed during the war, those of *Rüdesheim*, *Remagen* and *Neuwied*. (Example Remagen : central span 184 m. 21 (604 feet), side spans 84 m. 60 (277 ft. 7 in.).

The makers have also substituted straight parallel flanged girders in the side spans, instead of arched girders, as in the *Süd Brücke*.

In elevation, it does not appear that the beauty of the design has suffered by this arrangement. It is evidently a question of taste, but it is probable that at least, so far as the Remagen and Rüdesheim bridges are concerned, this solution is superior to that of the consecutive arches in the *Süd Brücke*. From the point of view of economy in material, it is not possible to make a comparison as regards weight, the form of cross section and the arrangement of windbracing being so different. If, however, there is some saving effected in the arched as against the parallel flanged girder side spans, it would probably be hardly noticeable in the spans in question 80 to 90 m. (262 1/2 to 295 1/4 feet).

If we examine the two solutions of straight span or arched span from the point of view of their use in railway bridges, the transverse stability of the closed frame of a straight bridge with parallel flanges is much greater than the corresponding cross section of the bridge with arched top boom, and also its stiffness to resist the rolling loads will be greater. Therefore, so far as this is concerned, the solution obtained in the Remagen bridge is preferable to that at Cologne. The design of the arched trusses of the Rüdesheim railway bridge is more complicated than those of the Neuwied and Remagen bridges and necessitates a wider spacing between the verticals from which the platform is suspended, thus causing less transverse stability.

We must therefore conclude, that so far as the general arrangement of the main girders is concerned, except in special cases, the design of the Remagen

and Neuwied bridges offers the best solution to the problem involved.

§ 2 — Flooring.

The flooring of these bridges is uniformly constructed of longitudinal rail bearers and cross girders slung to the main girders by suspension verticals.

The longitudinal rail bearers, which are generally fairly long, are braced together with angle iron frames. These frames are generally fixed at the third and the two thirds of the length of the rail bearers.

According to the German custom, the distance between centres of the rail bearers is sometimes as much as 1 m. 90 (6 ft. 3 in.), which exceeds the standard gauge. This arrangement necessitates large sectioned wooden beams to support the rails. The advantage of this wide spacing of the rail bearers is to provide for slight discrepancies in the laying of the road, and to avoid any accidental overhanging of a rail. It also assists the cross girders.

The connection of the longitudinal rail bearers to the cross girders is generally made under the upper angle irons of the cross girder. This is a simple connection with vertical angle iron cleats between the top and bottom flange angle irons. This method of attachment is simple, but offers no stiffness crossways and exposes the cross girders to the whole of the longitudinal stress from the roadway. With these platforms, it is absolutely necessary therefore to provide means of resistance in the flooring against longitudinal stresses (brake action and adhesion) so as to reduce the cross bending of the bridge members, and the necessity of calculating them, so that they will resist the longitudinal forces.

Bracing to resist brake action (*Bremsverband*) which absorb these stresses and transfer them through the members of the lower windbracing to the supports are used in the construction of all railway bridges with metallic platforms in Germany.

In the first structures with horizontal ties (Worms, Mayence), and with platforms independent of the horizontal ties, there is only one stay for brake action solidly fixed to the horizontal ties in the centre of the platform.

In the bridges built after that at Mayence with horizontal ties fastened to the cross beams, spaces have been provided for in the roadway with corresponding stays. For instance, in the central span of the *Süd Brücke* at Cologne, three stays for brake action have been introduced fixed at a quarter, a half and three quarters the length of the platform.

The bridge at Neuwied is provided with a stay for four lengths of longitudinal rail bearers with corresponding gaps in the flooring.

These divisions or gaps in the flooring make it necessary to establish free expansion supports for the longitudinal rail bearers lying on the cross girders. In the first examples, these supports allow for a simple sliding motion, but in the later constructions (see the Rüdesheim arrangement), the toothed roller working on a rack is much more complicated.

These graps in the flooring are provided with the object of eliminating the distortion resulting from the variable stresses set up in the horizontal ties. The connection of the rail bearers and cross girders would be incapable of supporting these stresses. The over stressed rivets would soon become loose and the joints develop play which would be detrimental to the life of the platform.

It should be remembered that in many railway bridges in France, and particularly in Belgium, the connection of the rail bearers and cross girders is made by means *of plates connecting the upper flanges at the same level.*

This method, which gives great transverse stiffness to the flooring, makes it better for all the members to resist the stresses on the rails and obviates the necessity of using stays for brake action effects. In the construction of medium sized spans, the gaps in the flooring become, not only useless, but even detrimental, because the longitudinal rail bearers give an additional resistance difficult to estimate, but in no way negligible as far as the lower members of the main girders are concerned.

We must also remember that at the level of the upper surfaces of the rail bearers there exists a bracing to resist vibration which absorbs the lateral stresses of the road and the transverse stresses due to the wind on the flooring and on the trains.

§ 3. — Cross section.

When describing the Worms bridge, we pointed out the care that had been taken to render the main framing of the bridge as independent as possible of the distortion of the platform. This principle, the application of which was first suggested in the design got out by the « Société Harkort » of Duisburg for the Bonn bridge (not proceeded with), has been carried out as far as possible in the Worms railway bridge already described. The verticals from which the platform is suspended are hinged on to the cross girders and the horizontal tie hung on to the latter butts laterally against them.

In the Mayence bridge, which followed the Worms bridge in chronological order, the verticals are rivetted on to the cross girders. The horizontal tie, however, is still hung with lateral abutment against the cross girder.

In the *Süd Brücke,* the independence of the three members has totally disappeared. It is only, however, with the *Hohenzollern Brücke* and in the *Hamm bridge* that a rigid connection is found between the three elements by means of large triangular gussets for stiffening purposes between the verticals and the cross girder.

The principle of rigidity in the lower apex of the verticals has been maintained in the Rüdesheim, Neuwied and Ramagen bridges.

The verticals from which the platform is suspended have a double « T » section made up of a web and four angles with wings that are generally unequal, the larger wing being parallel to the plane of the girder. This arrangement is necessary to enable the verticals to resist the bending moment caused by a difference of temperature between the horizontal ties and the main girder (10° C. is generally allowed for).

§ 4. — Upper windbracing.

The upper windbracing and the cross framing between the girders have passed through a curious evolution in the structures we have dealt with.

In the *Bonn and Dusseldorf bridges,* we see for the first time an upper windbracing with intersecting diagonals and *hinged joints* following *the neutral axis of the upper boom.*

This curved girder conveys the transverse wind stresses on to two rigid portals in the plane of one of the end verticals, then to the supporting contri-

vances by projecting ends of the verticals suitably strengthened.

In the *cross planes of the vertical frames*, we also find two rigid lattice struts between the top and bottom booms or chords as well as intersecting diagonals (of little use).

The suspension verticals of the platform with the cross girders and the upper bracing make up therefore a series of rigid transverse frames in the platform. The principle of hinged connections with diagonals terminating whistle shape is only made use of in the curved girder of the upper windbracing.

In the *Worms bridge*, the upper windbracing girder stands alone. This is a girder with crossed bars having also jointed connections following the neutral axis of the upper member. The frame principle has totally disappeared, and the idea of « *Freischwebende Bahn* » dominates the whole scheme which ensures the independence of the arch framework and platform as regards distortion.

In the *Mayence bridge*, the freedom of the upper windbracing is further accentuated by the suppression of the cross strut of the windbracing system, the intersecting diagonal girders alone remaining.

The *Süd Brücke* at Cologne marks an evolution in the opposite direction. In it we still find the intersecting diagonal girders, but with rigid connections. The central span has, however, braced cross frames with upper struts in the middle panels.

The *Hohenzollern Brücke* and the *Hamm bridge* return to the principle of hinged joints. We may point out in passing that the idea of supplementary windbracing between the lower members of the central span of the *Hohenzollern Brücke* is not a happy one.

With the *Rüdesheim, Neuwied and Remagen railway bridges*, we return to our starting point. In them we find a curved girder for windbracing following the flanges of the upper booms. The apices of this girder are situated in the centre between the consecutive apices of the main girders. We find also the principle of rigid frames in the plane of the suspension verticals. These frames consist of the suspension verticals connected by large triangular gussets to the cross girders.

At the top, the main verticals of the girders are strengthened in the inside, forming with a plate web strut between the upper booms, rigid transverse portals making a rigid cross frame between the two main girders.

Contrary to the example and precedent of the *Hohenzollern Brücke*, only a single windbracing system between the upper booms has been provided (the central span of the Neuwied bridge has however a length of 188 m. [616 ft. 9 in.]). The effectiveness of this windbracing appears to be sensibly increased by the apices being placed half way between the apices of the main girders.

§ 5 — Bearings.

Theoretically, means should be provided to deal with the expansion taking place crossways as well as that in a longitudinal direction. This movement has been provided for in the Worms bridge by arranging a fixed spherical centre of distortion with the addition of roller bearings working parallel with and normally to the centre line of the structure. The width of these railway bridges being small in proportion to their length (1/11 to 1/18), it has been found in practice that these cross rollers are apparently useless, and in those

structures which followed in chronological order the Worms bridge, longitudinal expansion only was taken into account.

§ 6. — **Other special points.**

With all these structures, great care has been taken to provide convenient arrangements for inspection and upkeep of the various metal parts. An inspection trolley runs under each platform for the whole width, worked by hand by a system of gearing and running on the extreme edges of the lower flanges of the bottom chord.

For the inspection of the top members, the angles for staying the webs of the box girders have been lengthened at regular intervals in order to carry brackets to form an inspection gangway.

The inspection of the upper members of the Baerl bridge is effected by means of a trolley running on racks, one of which is hung on one side to the wind-bracing, and on the other to the boom.

The *flooring* of some of these structures carries a removable wooden covering to allow the passing of artillery in war time, an arrangement which also allows them to be used as road bridges (Mayence, Süd Brücke, Rüdesheim, Remagen, Neuwied).

III. — CONCLUSIONS.

This short account of the chief methods employed in designing these consecutively constructed bridges shows a curious and very instructive evolution in the ideas that prompted their general design and the various details in their construction. If we consider it from the railway engineer's particular point of view, we should notice with interest that the principle of relative solidarity between the various elements (Neuwied) seems to definitely predominate over that having the greatest possible independence (Worms). The latter system can only be justified by admitting the difficulty for providing for, with sufficient accuracy, the reactions that take place between the members of large structures. It would also be necessary to balance up the advantages of this more exact static calculation with the inconvenience of the relatively greater freedom of motion of the members under the action of dynamic loads.

We are op opinion that the essential point about a railway bridge is the perfect solidarity that should exist between all the members, thus ensuring the least possible amount of distortion to occur in the structure. It is hardly necessary to refer to the complexity and variable nature of the stresses produced on the road by large modern engines, and how necessary it is that an intimate union between all the parts should contribute to the general bearing of the whole structure.

An important factor in this respect is the resistance to distortions of the cross section. The large arches which have been described are badly arranged from this point of view, the connection between the platform and the main girders being effected by means of long flexible tie rods without sufficient transverse

rigidity. The freedom of motion in these structures is very perceptible and quite easily noticed when a train is passing over. It is no doubt the desire to reduce the distortion that occurs and the relative motion of the various members that has led the designers of the later structures to adopt the system of transversal frames.

The upper windbracing should also greatly contribute to obtain the result in view. Concerning this, if we may admire the lightness and boldness of the arrangements adopted in the methods of construction, we may ask ourselves if a greater rigidity in the connecting together of the parts would not more effectively contribute to the good working of the whole.

We may mention in passing that the last German rule for the calculation of railway bridges is in reference to the transverse rigidity in open bridges, and requires a test making of the verticals with respect to transverse bending.

In bringing this truly attractive subject of the evolution of the methods of construction to an end, we may acknowledge that with the exception of a few criticisms of details, the problems that have been put forward have all been remarkably well thought out and solved, especially if we take into account all the negligible secondary stresses in small structures, but the importance of which increases rapidly with the length of the span.

We are hoping to give in a later article an account of the methods used in the various calculations, giving the particular conditions which had to be taken into account as far as these are concerned.

December 1923.

[625. 214]

Journal boxes with anti-friction bearings.

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Figs. 1 to 3, p. 555.

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In view of the comparatively limited extent to which vehicles on rails have been equipped with anti-friction bearings it may appear premature to discuss the question of standardization of journal boxes for such bearings at the present time. The available experience, however, indicates quite clearly certain lines which should be followed in the design of such boxes, in the interest of the railroads as well as of the bearing manufacturers. They may appear obvious, but the fact that they are not generally recognized and followed, makes it appropriate to state them.

Advantage of standard bearing sizes.

The proposed international standardization of ball bearings, which at the present time is being extended to cover all bearing sizes that might be considered for use in journal boxes, restricts the choice of bearings to a limited number of types and sizes.

To use bearings of special outside dimensions should be discouraged because the grading of standard bearings is fine enough to meet all practical requirements. The use of standard bearing sizes enables the railroad to substitute other makes for the one originally selected, if it should later appear desirable to do so. International standard size bearings are cheaper to buy and can be supplied from stock or on short notice from various manufacturers in different countries.

The proposed international ball bearing sizes are intended to apply to roller bearings as well and will be followed by many leading roller bearing manufacturers. For vehicles on rails it may be taken for granted that only precision roller bearings will be used to any appreciable extent, at least for all applications where the service is comparatively severe and considerable shock loads may occur. On account of their limited shock load capacity, ball bearings have not proved satisfactory for such service.

The question of the type of bearing.

A fundamental question in regard to the design of such boxes is whether one or more bearings should be used in each box. In early Swedish designs two self-alining ball bearings were used in each box, one of which carried radial as well as thrust load, while the other carried radial load only. This arrangement was used for freight and passenger cars, while two self-alining radial bearings and one thrust bearing were used for locomotive boxes to take care of the much higher thrust loads that are to be expected.

If journal boxes are equipped with self-alining ball or roller bearings, there is good reason to equip each box with two bearings, because one would not main-

tain the relative positions of box and axle. It is, however, possible to guide the box from the outside and at least one successful installation is in operation with only one self-alining roller bearing per box. If rigid roller bearings are used, one bearing per box is sufficient. If the wide series are used and this arrangement proves to be successful, it should be adopted wherever possible.

The single bearing box.

The following may be considered as the main advantages of the single bearing box as compared with the two or more bearing boxes. First, a solid box covered by one cap may be used. As a rule, two or more bearing boxes are required to be either horizontally split or to have two covers for each box in order to facilitate the mounting and removal of the bearings. Horizontally split boxes were eliminated from modern box construction years ago and railroad engineers are, for very good reasons, strongly opposed to such boxes. Second, one bearing is easier to install, inspect and remove than two or more bearing boxes. Third, the bending moment, caused by the load on the journal box and acting on the axle section at the shoulder of the inside bearing, is smaller in case of the single bearing, on account of the smaller leverage. Consequently it is possible to use a smaller bore for the single bearing than for the inside bearing in a box with two or more bearings. The outside diameter of the single bearing can, in most cases, be made smaller than the outside diameter of the inside bearing in a two-bearing box of the same load carrying capacity. Fourth, the single bearing box is, therefore, smaller, lighter and cheaper than the corresponding box with two or more bearings and is easier to adapt to existing car truck designs.

The load conditions of a railway journal box are such that they are easily met by one bearing of proper design. They are entirely different from those in the front hub of an automobile, for instance, where the arrangement of two bearings is preferable.

Loading conditions of a journal box.

In the case of vehicles running on rails, the wheels are rigidly mounted on the axle, while automobile front wheels turn on a stationary axle. Referring to figure 1, a force K_1 acting on the rim of an automobile wheel in the direction of the axle, is effectively taken up by the two forces K_1 and K_2 reacting through the two roller bearings in the hub.

The corresponding thrust force K, which is similar in the case of vehicles on rails, is comparatively small and does not exert any turning moment on the journal box bearing because the wheels are firmly mounted on the axle as shown in figure 2. Such turning moments as may be exerted on the journal box by thrust forces transmitted to the box through the spring or the pedestals, are so small that they can easily be taken up by any roller bearing of the rigid type. The load conditions, therefore, do not justify the arrangement of two or more bearings per box.

Relation of load and bearing.

The next question to decide is how to place the single bearing in relation to the load acting on the journal box. In order to avoid producing a turning moment which this load would ordinarily do in a longitudinal plane of the bearing, it is of course advisable to place the bearing directly under this force so that the weight of the load passes through the transverse central plane of the bearing.

Selecting the proper type of bearing.

Most railroads prescribe a certain maximum bending stress in the axle caused

by the static load, and on this basis it is possible to ascertain the maximum load which may be permitted to act in the transverse central plane of any standard roller bearing.

In selecting the proper bearing type, preference will as a rule be given to the wide type of the heavy series, due to the fact that these bearings have the largest load carrying capacity for a given outside diameter or the smallest outside diameter for a given carrying capacity. A small outside diameter is desirable because the space between the center of the axle and the top of the journal box is often limited.

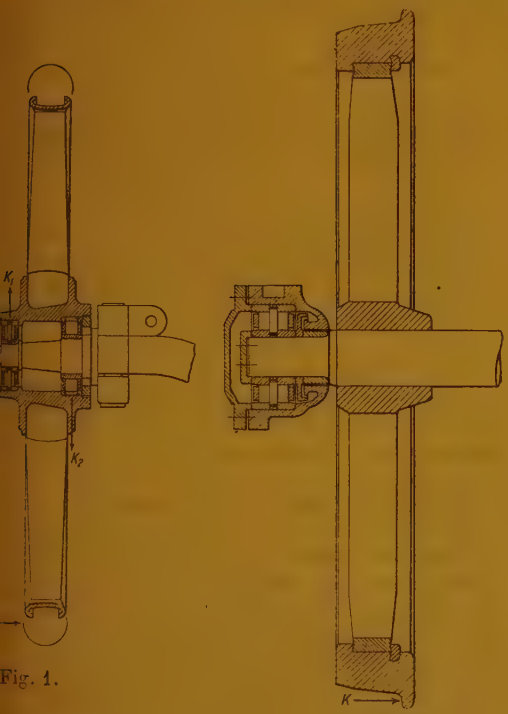

Fig. 2.

trast between automobile and railway car journal bearing conditions.

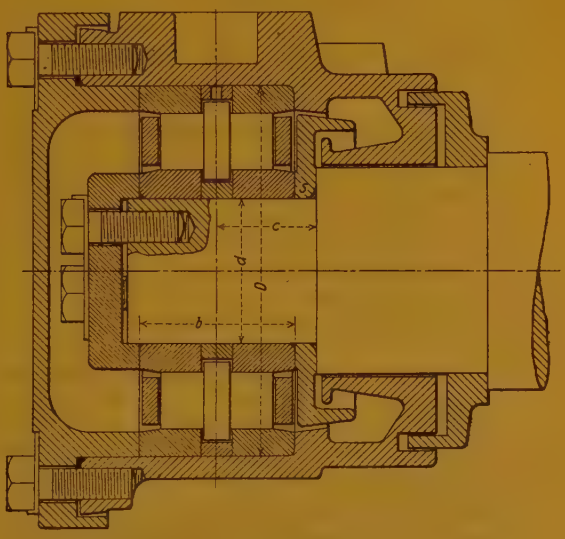

Fig. 3.

Sectional view of car journal with single roller bearing, showing dimensions for which standardization is proposed.

The dimensions of the roller bearings of the wide heavy series are given in table I. The values given correspond to the latest proposals for international standards for such bearings. Assuming that the maximum permissible bending stress which may occur in the axle end is known, it is then possible to calculate the maximum static load for which each bearing of the above series may be used without exceeding the maximum permissible bending stress. If we let :

Q = the maximum static load on the bearing in pounds, within the limits of the permissible bending stress in the axle.

C = the distance of the bearing center

from the axle shoulder against which the bearing is held, or from the section of the axle in which the greatest bending stresses occur.

K_b = the maximum permissible bending stress in lb. per square inch prescribed by the railroad for the service in question.

d = the bore of the bearing in inches.

A = a constant $= \frac{0.1d^3}{C}$.

Then we can derive the equation

$$Q \times C = 0.1 d^3 K_b \quad \text{or} \quad P = AK_b.$$

The constant A is different for each bearing bore and depends also upon the distance C. This is composed of half the width of the bearing and sometimes of an additional distance which differs according to the arrangement of the bearing on the shaft.

The following calculations apply to a concrete case : namely, the usual type of a Jaeger roller bearing journal box, as represented in figure 3. In this design a disk S is inserted between the roller bearing and the shaft shoulder, which disk occupies a space in the direction of the axle of about 10 mm. It is provided with a large fillet and, therefore, it is very conservative if we assume that

C = 1/2 the width of the bearing + 10 mm.

On this basis we have calculated the values of C in table I. The corresponding maximum values of Q are obtained by multiplying these values by the maximum static bending stress in the axle permitted by the competent authority. The table also contains the catalogue loads of the wide Jaeger roller bearings of the heavy series for 200 and 500 revolutions per minute.

The following example will illustrate the use of table I : The new, large freight cars of the German state railways are partly equipped with Jaeger roller bearings of 100 mm. bore, which is equal to 3.9370 inches. The maximum static load per box is 10 000 kgr., or 22 000 lb. The maximum permissible bending stress in the axle is 700 kgr. per cm², or about 10 000 lb. per square inch. The maximum speed is 60 km. per hour, or about 37.5 miles per hour. The distance C = 49 + 10 = 59 mm., or 2.3229 inches, and consequently

$$A = \frac{0.1d^3}{C} = 0.1 \times \frac{3.9370^3}{2.3229} = 2.64.$$

We thus find, according to the preceding formula, that

$$Q = AK_b = 2.64 \times 10\,000 = 26\,400.$$

The bearing load should thus, in view of the maximum permissible bending stress in the axle, not exceed 26 400 lb. As the maximum load only amounts to 10 000 kgr., or 22 000 lb., the axle is amply strong. It is thus in every case easy to ascertain whether a bearing from this point of view is suitable for a certain application.

Ratings of anti-friction bearings.

The maximum bearing load must furthermore be smaller than the load carrying capacity of the bearing at the maximum speed at which it has to operate. In order to obtain this load carrying capacity, the catalogue load of the bearing has to be divided by a certain safety factor.

Unfortunately, the catalogue loads of the various anti-friction bearing manufacturers are established on an entirely different basis and can, therefore, not be compared. At times, the ratings of equivalent bearings differ as much as 100 % in the catalogues of different manufacturers.

In case of the Jaeger roller bearings, which have a very conservative rating, it is sufficient to use a factor of safety of 1.3 for journal box bearings, while other

TABLE I.

BEARING NUMBER.	Bored.		Outside diameter.		Width W.		Radius T_1.	Distance C.		Catalogue load in thousands of lb. at		Constant A.	
	Mm.	Inches.	Mm.	Inches.	Mm.	Inches.	Mm.	Mm.	Inches.	200 revolutions per minute.	500 revolutions per minute.	In cm².	In square inches.
3 410	50	1.9685	130	5.1181	53	2.0866	1.0	36 5	1.4371	8 4	7.1	3.4	0.527
3 411	55	2.1654	140	5.5118	57	2.2441	1.5	38.5	1.5158	9.3	7.9	4.3	0.667
3 412	60	2.3622	150	5.9055	60	2.3622	1.5	40	1.5748	10.5	8.9	5.4	0.838
3 413	65	2.5591	160	6.2992	64	2.5197	1.5	42	1.6535	11.5	9.8	6.5	1.01
3 414	70	2.7559	180	7.0866	74	2.9134	1.5	47	1.8504	14.7	12.5	7.3	1.14
3 415	75	2.9528	190	7.4803	77	3.0315	1.5	48.5	1.9095	15.8	13.6	8.7	1.35
3 416	80	3.1496	200	7.8740	80	3.1496	2.0	50	1.9685	17.5	14.8	10.3	1.60
3 417	85	3.3465	210	8.2677	86	3 3858	2.0	53	2.0866	18.3	15.6	11.6	1.80
3 418	90	3.5433	225	8.8583	90	3.5433	2.0	55	2.1654	22.3	18.7	13.3	2.064
3 419	95	3.7402	240	9.4488	95	3.7402	2.0	57.5	2.2638	25.8	21.7	14.9	2.314
3 420	100	3.9370	250	9.8425	98	3.8583	2.0	59	2.3229	30.5	25.8	17.0	2.64
3 421	105	4.1339	260	10.2362	100	3.9370	2.0	60	2.3622	35.3	29.9	19.2	2.98
3 422	110	4.3307	280	11.0236	108	4.2520	2.0	64	2.5197	41.0	34.6	20.3	3.15
3 424	120	4.7244	310	12.2047	118	4.6457	2.0	69	2.7166	46.7	38.2	25	3.88
3 426	130	5.1187	340	13.3858	128	5.0394	2.5	74	2.9134	52.9	43.7	29.7	4.61
3 428	140	5.5118	360	14.1732	132	5.1968	2.5	76	2.9922	58.6	49.2	36.2	5.62
3 430	150	5.9055	380	14.9606	138	5.4331	2.5	79	3.1103	64.8	53.4	42.8	6.65
3 432	160	6.2992	400	15.7480	142	5.5905	2.5	81	3.1890	70.3	58.2	50.7	7 87
3 434	170	6.6929	420	16.5354	145	5.7087	3.0	82.5	3.2480	75.6	63.3	59.7	9.27
3 436	180	7.0866	440	17.3228	150	5.9055	3.0	85	3.3465	80.7	68.8	68.7	10 67
3 438	190	7.4803	460	18.1102	155	6.1024	3.0	87.5	3.4449	85.1	...	78.3	12.15

TABLE II.

Range of diameters.	Corresponding tolerance limits for bearing bore and outside diameter. Minimum = 0.		Shaft diameter.				Housing bore.			
	Minimum.		Maximum.		Minimum.		Maximum.		Minimum.	
	Mm.	Inches.	Mm.	Inches.	Mm.	Inches.	Mm	Inches.	Mm.	Inches.
Above 30-50	0.012	0.0005	0.003	0.0001	0.021	0.0008	...	...	...	...
— 50-80	0.015	0.0006	0.005	0.0002	0.025	0.001	...	...	...	...
— 80-120	0.020	0.0008	0.009	0.0004	0.031	0.0012	...	...	...	...
— 120-180	0.025	0.0010	0.012	0.0005	0.038	0.0015	0.040	0.0016	0.013	0.0005
— 180-260	0.030	0.0012	0.015	0.0006	0.045	0.0018	0.045	0.0018	0.015	0.0006
— 260-360	0.035	0.0014	...	...	...	...	0.060	0.0024	0.018	0.0007
— 360-500	0.045	0.0018	...	...	...	...	0.070	0.0028	0.020	0.0008

bearings, which have about double the catalogue rating, require a factor of safety of 2.6 or more.

In the case under consideration we find that the maximum speed of the axle is 300 revolutions per minute, for which speed a catalogue load of 13 000 kgr. or 28 600 lb., can be computed. For the existing maximum load of 10 000 kgr., the corresponding factor of safety is thus 1.3, which is sufficient.

Suggested basis for standardization

On the basis of the above considerations, the writer suggests that all designs of railroad journal boxes, to be equipped with anti-friction bearings, be standardized as to the following points: First, bearing sizes should be specified according to the proposed or accepted international standards for ball bearings. Second, each journal box should be a solid steel casting, simply closed by a front cover. Third, the box should contain only one roller bearing and the center line of the load on the journal box should pass through the center of the bearing.

Table I contains in addition to the main dimensions of the standard wide heavy series, also the maximum radii of the shaft shoulder and bearing housing fillets, T_1, which may be used in connection with these bearings.

For the convenience of the users, we give in table II the internationally proposed bearing tolerances as well as the axle and housing tolerances, which should be specified.

The German state railways are at the present time preparing or making extensive tests with a number of different anti-friction journal box designs furnished by the various prominent German ball or roller bearing manufacturers, and it is interesting to note that the designs of Jaeger, Krupp, Riebe-Werke, Fichtel & Sachs, follow the above suggested lines of box design, using one centrally located bearing in each box, while two equally

prominent manufacturers use two or more bearings per box.

Summary.

The author suggests as a basis upon which to standardize journal boxes with anti-friction bearings for vehicles on rails the following for consideration : First, bearings of the proposed international standard sizes should be selected. Second, each journal box should consist of one solid housing closed by a front cover. Third, the box should contain only one bearing and the center line of the load should lay in the transverse central plane of the bearing.

This information will enable the designer to calculate the space needed to apply anti-friction bearings to any truck.

[656 .212.5 (.73)]

Markham Yard, Illinois Central,

By W. P. CRONICAN,

CHIEF DRAUGHTSMAN ILLINOIS CENTRAL RAILROAD,

and

ABNER BERNARD,

SUPERINTENDENT PASSENGER SERVICE ILLINOIS CENTRAL RAILROAD.

Fig. 1, p. 560.

(From the *Railway Review*.)

Markham Yard, now under construction by the Illinois Central Railroad will be, when completed, one of the largest hump operated terminals in the country. It is located about 21 miles south of the Chicago river, between the towns of Harvey and Homewood, adjacent to the main line of the railroad. At the present time the yard is about 60 % complete.

Rapid development in the design of steam locomotives, with the consequent increase in power and efficiency during the past decade, has made possible greater economies in railroad operation by making possible longer and fewer trains. Perhaps the greatest single item of these economies is the reduction in the number of crews required to handle a given number of cars. It is safe to say that the trains of to-day have three times the gross tonnage of those of fifteen years ago; prior to that time the existing Illinois Central Railroad yards at Chicago, namely : Wildwood yard at 127th street, Fordham yard at 90th street, and the South Water street terminal, were of ample size to handle the business. Business conditions during the period of the late war were generally conceded to be somewhat inflated and a speedy return to normal conditions following the cessation of hostilities was predicted.

Traffic and train tonnage steadily increased until it became impossible to handle the trains in the yards mentioned without doubling over onto other tracks. This condition greatly increased the switching necessary for classification

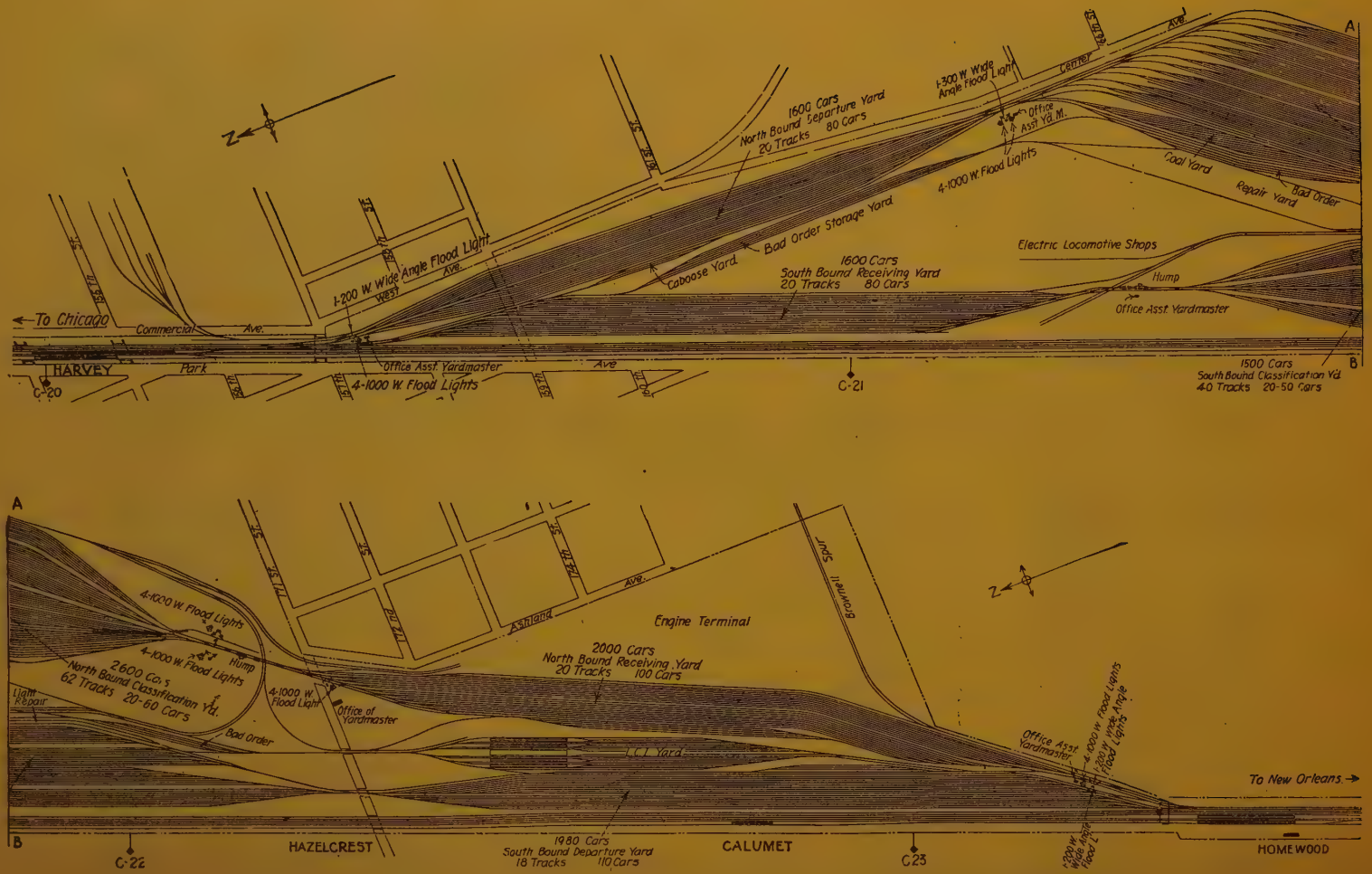

Fig. 1. — Arrangement of tracks and terminal facilities, Markham Yard, Illinois Central Railroad.

and making up of trains, and the corresponding cost increase at terminals mounted to a point out of all proportion to what it should have been. The absence of tracks long enough to accommodate a full tonnage train made it impossible to properly test the train air line before it was despatched, without moving the train onto the main tracks. This meant the tying up of the main until the test was completed.

Various schemes were proposed for the expansion of the existing yards, but it was found after careful study that no successful plan could be worked out, and studies were begun and preliminary plans drawn up for the new yard.

It was found that during the month of March, 1918 the number of loaded cars arriving in Chicago from the south was 33 899, or an increase of 16 000 cars over the same month in 1913. This represents an increase of 90 %. Bear in mind that this was arriving business only. Add to this an equally large increase in the number of cars moving south and the conditions existing at the time construction of Markham yard was authorized, not only as a desirable, but as an absolutely necessary measure, can be visualized.

The usual problem of securing a proper site for the yard did not prove difficult. The tract selected, comprising about 400 acres, lying east of the right of way and extending for three miles between the city of Harvey and the village of Homewood, offered almost all of the desired features. This land was practically vacant, with few streets, and, with the exception of a few acres of platted property within the corporate limits of Harvey and Homewood, the entire tract was purchased as acreage property. The tract was far enough south to offer a suitable terminal for steam power coming from the south and for the proposed electric power moving to the South Water street terminal. The natural rise in the surface is about fifty feet between Harvey on the north and Homewood on the south, thus making the grading requirements for the north bound section of the yard much smaller than would be expected. Since most of the trains moving south from the yard have less tonnage than the entering north bound trains, the gradients of the south bound unit of the yard could be reasonably increased over those of the north bound section.

The grade crossing situation at the streets of Homewood and Harvey had long been a serious problem for fast operation through the towns, and it was finally decided to elevate the main tracks and thus eliminate all grade crossings in the vicinity of the yard. With this concession on the part of the railroad, very little difficulty was experienced in securing the necessary ordinances covering the vacation of several streets crossing the yard, and the entire matter affecting the towns in the vicinity was handled to the satisfaction of all concerned without litigation. The necessity of elevating the tracks through Harvey to eliminate the street crossings at grade greatly simplified the problem of the grade crossing with the Baltimore & Ohio Chicago Terminal Railroad and the Grand Trunk Western Railroad, and in this way facilitated the program for the Chicago terminal development work which calls for the elimination of all railroad grade crossings.

The two roads mentioned have heretofore crossed the Illinois Central main tracks at grade just south of 152nd street, and near the center of the city. The Grand Trunk Western Railroad maintained a double track crossing and the Baltimore & Ohio Chicago Terminal Railroad, a single track crossing about 120 feet to the south of it.

A desirable feature of the site selected is, that it lies south of all the important interchange points with other railroads entering Chicago. This makes it unnecessary to move cars intended for deli-

very to these roads beyond the actual interchange points.

Nearly all of the grading for Markham yard, amounting to approximately 4 000 000 cubic yards, will be embankment. A light cut will be necessary in the south bound section at the Homewood end. The fill at the north end of the yard is increased by the elevation over 159th street. The maximum height of fill is at the humps, where a 27-foot embankment is required in the north bound, and a 30 foot fill in the south bound section.

Sand for embankment was first taken from property purchased for a borrow pit a mile east of the yard, but later was secured from the dunes near Miller, Ind. The borrow pit yielded approximately a million and a half yards, and the contractors are now furnishing filling from a pit near the original pit. It is estimated that this new pit will yield approximately 900 000 cubic yards. Considerable material for embankment has also been obtained in the form of industrial refuse collected at points in and around Chicago.. This has been unloaded from cars by locomotive cranes.

The maximum gradient in the north bound section, aside from the hump itself, is 0.35 %. This gradient is made necessary on account of the elevated main tracks at Harvey. The maximum gradient in the south bound section is 0.55 %, approaching the main tracks at Homewood. The humping gradients were established after an exhaustive study of similar humps throughout the country, and the operation of the hump yard at Centralia, Ill.

Markham Yard consists of two principal sections, one for north bound and the other for south bound traffic. Each section is composed of receiving, classifying and departing units. In addition, a l. c. l. transfer yard with five 700-foot transfer platforms, a 1 000 car repair yard, complete modern icing facilities, and a 60-stall engine terminal will be constructed within the limits of the yard.

The north bound receiving unit consists of twenty 100-car tracks divided into groups of ten tracks spaced on 13.5 foot centers, with a 19-foot space between groups. Twelve of the tracks are now built. The remaining eight will be built as necessity requires. It is intended that incoming trains will be held in this yard until ready to go over the hump. In conjunction with the north bound receiving yard five additional 50-car tracks have been provided for cars requiring reclassification.

The hump end of the north bound receiving yard is arranged with two parallel ladder tracks leading directly over the hump. Movement from the yard tracks to the secondary ladder track is accomplished by means of slip switches in the main ladder. In all cases the train passing over the hump will use the secondary ladder, leaving the main ladder clear, so that an engine pulling a train into the yard while another is being humped can uncouple and use the main ladder to proceed to the engine terminal. This is one of the prominent features in the design of Markham yard and it will undoubtedly prove an economy.

When a train arrives from the south it will pull directly into the receiving yard. The engine will uncouple and move to the engine terminal in the manner described. The conductor will deliver the waybills to the assistant yard master at the throat of the yard who will forward them to the general yardmaster, probably through pneumatic tubes. A car checker will be dispatched along the train with the conductor's record, to check the car and seal numbers. He will chalk on the end of the car the number of the track into which the car is to be humped, and note such number on the record. When he has finished checking he turns the records over to the weigh master who notes the car number, class of car and lading on his blotter, in the exact order in which the cars will move over the scale. A list of the cars and the tracks

into which they will be humped is delivered to the towerman. This list is arranged in the order in which the cars will pass over the hump, so that the towerman knows in advance just where each car is to go. The train is now ready to be humped.

The humping engine will detach the caboose and move it to a caboose grid adjacent to the south bound departure yard, where it is picked up when needed by the make-up engine working in the south bound units, and coupled to a south bound train. This affords a very direct movement for cabooses and requires them to be moved only the length of the south bound departure unit.

After disposing of the caboose the hump engine will return to the rear of the train and at a signal will push it over the hump. The hump grades at Markham will permit a humping speed of three miles per hour when business warrants. At other times a speed of two miles per hour is preferable.

Before the car reaches the apex of the hump it is boarded by a car rider who will, in all cases, test the hand brake before the car is detached. If the brake is found defective, the car is moved closer to the scale before it is uncoupled, so that its speed is restricted. Skate men must be stationed in the classification yard to take care of these cars, if necessary. In case this is done the skate man is notified where to place the skate and the car will proceed into the yard.

The hump in the north bound unit is located just north of 171st street. It has been designed for the use of a mechanical hump at the apex and a 60 feet, 150 ton automatic recording scale located just below. The distance from the center of the mechanical hump to the center of the scales is 101.5 feet, with 35 feet of 3.25 % gradient. This affords a maximum weighing speed of 7 miles per hour. It is approximately 3 000 feet from the scales to the lower end of the classification yard and gradients have been fixed to give a velocity of 11.7 miles per hour at the end. The scale is laid on a 1.0 % descending gradient, which increases to a 3.0 % gradient for 95 feet after leaving the scales. This gradient meets a 2.0 % grade for 158 feet and then a 1.0 % grade into the yard.

Some criticism has been offered because of the proximity of the first switch of the classification yard to the mechanical hump. It has been suggested that the cars may run too close together to permit the operation of this switch between cars going to opposite sides of the yard. Due to property restrictions it was found necessary to reduce this space from a desired 400 feet to 268 feet in order to secure desired track lengths in the yard. This is a violation of a characteristic of nearly all hump yards, but it is maintained that the speed of the humping train governs the time interval between the cars, and this interval will not be materially decreased in this distance, even in the case of a loaded car following an empty. With the maximum humping speed of three miles per hour the time interval between cars is approximately nine seconds. In the case of a loaded car following an empty this interval will be decreased to seven seconds when the switch in question is reached. Seven seconds is considered ample time in which to throw the switch. When the humping speed is slower the interval will be correspondingly greater.

The north bound classification yard has 62 tracks, not including a grid of thirteen tracks for commercial coal, and the necessary tracks for both light repair and bad order cars. The tracks vary in length from twenty to sixty cars, the short tracks being used for industrial classifications. The total capacity of this unit is 2 600 cars. Tracks are divided into groups of ten, with a ladder for each group at the hump end and a separate ladder for each five tracks at the lower end. Tracks are spaced 13.5 feet centers with 19 feet between groups. Each two

groups are separated by a space of 34 feet, giving three routes into the yard for the electric rider cars, three of which will be used, each operating on an independent track.

Since the matter of car riders is a large item in the expense of operating a hump, it is important that consideration be given to a method for quick return of these riders to the hump after they have taken the car to its proper place in the yard. These facilities have not as yet been constructed in Markham yard, but they will be before full operation is started.

A careful study has been made of the operation of the hump yard at Centralia, Ill., to determine the saving effected by carrying the car riders back to the hump after they have taken the car into the classification yard, instead of letting them walk back. It has been ascertained that a material saving in the cost of operation is made by the use of cars to return the riders to the hump.

The car recommended for this purpose is standard gauge with a short wheel base to permit its operation on sharp curves, and 20 feet in length, with the cab mounted at the front, well above the body to permit unobstructed view while operating forward or backward. A foot board is provided for the riders with a grab iron at shoulder level on the sides and rear. The cars will operate from the hump through 14-foot reinforced concrete tunnels at the throat of the yard leading into the 34-foot spaces already mentioned. The approaches to the tunnels will be on 6.0 % grades for approximately 400 feet, with twenty-four degree curves at the portals. The cars will operate at a speed of twenty miles per hour, slowing down at the tunnels to insure safety. At this speed it will be possible for a car to run into the yard, pick up the riders and return in five minutes.

Attempts have been made to develop a formula for the number of car riders necessary to keep a hump in continuous operation, but varying conditions have made this impossible. In this case the number required can only be determined by actual experience, but it is estimated that with the rider cars described the north bound hump can be operated to capacity with twenty riders.

All switches at the hump end of the classification unit are electrically operated from a tower on the hump. The tower is so situated that the operator overlooks the entire yard. The control in the tower will be the push buttons type now in common use at yards throughout the country. In order to facilitate the electric control system and simplify the operation at night, the ladder tracks have been built parallel to each other along spaces left for the rider tracks. This method introduces extra curvature, but the additional resistance to the moving car due to this curvature is taken care of in the grades. All switches are No. 8's and all curves are ten degree.

A trimmer engine stationed on the hump will proceed into the classification yard as soon as the last car of the train has passed and trim the yard as needed, while the hump engine returns to the rear of the next train.

At the outlet of the classification yard it was necessary, because of property limitations, to provide a ladder for each five tracks and to connect each ladder to the departure yard leads with a ten degree curve. There is a slight disadvantage to this plan in the large number of switching leads, but this is more than compensated for in the increased length of tracks made possible by this arrangement.

The north bound departure units consists of twenty 80-car tracks spaced on 13.5 feet centers. A space of 17 feet has been left between each five tracks to permit erection of poles to carry the overhead construction when the freight tracks are electrified into the city. Ten

tracks are now laid; the other ten will be built as necessity requires.

At the north end of the departure yard a complete air plant will be installed to test and charge the train lines before the train is despatched. Two electrically driven air compressors will be used to supply the air for this purpose. The test will be made while the train stands in the departure yard and before the steam or electric locomotive is coupled on. A similar plant will be located at the south end of the south bound departure yard.

The south bound units are similar in arrangement to the north bound. The grading is about 75 % complete at this time, but very little of the track work has been done. The south bound receiving unit will consist of twenty 80-car tracks, twelve of which will be built at the present time. The classification unit will consist of forty-two tracks of varying lengths to hold twenty to fifty cars, with a total capacity of 1 500 cars. Two rider tracks will be operated through the yard. The departure unit will consist of twenty 110-car tracks, ten of which will be built at the present time. These tracks are built to accommodate 110-car trains of empty coal cars moving south to the mines.

The less than car load transfer yard probably will be located between the north bound receiving unit and the south bound departure unit south of 171st street. The plans provide for standing 150 cars at the transfer platforms. Arrangements have been made for tracks leading directly from the classification yards into the l. c. l. yard. Switching of cars, when necessary, will be done in the l. c. l. yard itself. No sorting will be necessary at the classification yards, other than the ordinary segregation of cars containing l. c. l. freight.

Plans for car repair facilities have not yet been approved, but it is probable that a bad order storage yard with a capacity of 1 000 cars will be located between the classification yards. Bad order cars will be humped into grids so located that a quick transfer can be made into the storage yard. From the storage yard they will be moved as needed into the repair sheds located adjacent and parallel to the north bound classification unit. Light repairs to cars will be made on two tracks provided for this purpose at the sides of the classification yards.

The engine terminal will be located either adjacent to the north bound receiving yard or between the north bound departure yard and south bound receiving yard. Objection to a more central location has been made because of the probability of smoke drifting across the classification yards and obscuring the view of the towermen and riders. Probably the determining factor for the location of the mechanical facilities will be the shortest run for the road freight crews and engines after leaving the train.

Definite design for the engine terminal has not as yet been approved. It is probable, however, that twin, 30-stall houses will be used. Turntables 100 feet in length are considered sufficient to handle the power used on this division. Double track, deep water quenching cinder pits 250 feet long will, in all probability, be adopted. The coaling plant probably will be the elevating, automatic bucket type of 1 200 to 2 000 tons capacity. It has been estimated that the engine terminal will be required to handle from 150 to 200 engines per day during the busy seasons, so the entire arrangement will be made as flexible as possible.

Double track engine subways of reinforced concrete will be constructed to permit locomotives to pass under each hump.

Lighting for the yard will be provided by 1 000 watt flood lights located in batteries of four lights each on 75-foot steel towers at the ends of each unit. The poles for the lighting circuit will be set in the center of each unit so that local lights may be installed on the poles, if

found necessary. Power at 2 300 volts, 60 cycle, 3 phase, will be centrally delivered to the yard circuit.

All yard offices will be interconnected by pneumatic tubes, as well as telephones.

Markham yard, when fully developed, will contain approximately 175 miles of track. It will have a standing capacity exceeding 12 000 cars and a working capacity of 6 000 cars per day.

[385 .3 (.08 (.73) & 621. 138 (.73]

Twelfth annual report of the bureau of locomotive inspection to the Interstate Commerce Commission of the United States.

Figs. 1 to 3, p. 568.

(*Railway Mechanical Engineer.*)

The twelfth annual report to the Interstate Commerce Commission by A. G. Pack, chief inspector of the Bureau of Locomotive Inspection, for the fiscal year ending 30 June 1923, shows a marked increase in the number of defects and accidents due to the abnormal prevailing conditions. An abstract of the report follows :

The percentage of locomotives found defective increased from 48 % during the preceding year to 65 %, and the total number of defects increased approximately 70 %. The deteriorated condition of motive power is sharply reflected in the increased number of accidents and casualties. A comparison of accidents and casualties during the year as compared with the preceding year shows an increase of 117 % in the number of accident, 118 % in the number killed, and 120 % in the number injured.

Records covering locomotive failures indicate that the number of locomotive miles per locomotive failure decreased as much as from 50 to 70 % during the year as compared with the preceding year. Every locomotive failure caused by physical defects carries with it potential injury to persons, serious delay to traffic, and heavy property damage.

During the year there were 57 boiler explosions which resulted in the death of 41 persons and the serious injury of 88 others, an increase of 75 % in the number of such explosions, 86 % in the number of persons killed, and 93 % in the number injured, as compared with the preceding year. While most of these explosions were caused by the crown sheet having become overheated due to low water, the number of such cases where contributory defects or causes were found increased approximately 135 % as compared with the preceding year. The contributory causes found clearly establish the necessity for proper inspection and repair of all parts and appliances of the locomotive and tender.

Locomotives inspected and defects found.

	1923	*1922*	*1921*	*1920*
Locomotives reported	70 242	70 070	70 475	69 910
— inspected	63 657	64 354	60 812	49 471
— defective	41 150	30 978	30 207	25 529
Percentage inspected found defective	65	48	50	52
Locomotives ordered out of service	7 075	3 089	3 914	3 774

Accidents caused by the failure of some part of appurtenance or the boiler.

	1923	*1922*	*1921*	*1920*
Number of accidents	509	273	342	439
— killed	47	25	51	48
— injured	594	318	379	503

Accidents caused by the failure of some part or appurtenance of the locomotive and tender, including the boiler.

	1923	*1922*	*1921*	*1920*
Number of accidents	1 348	622	735	843
— killed	72	33	64	66
— injured	1 560	709	800	916

Derailments and accidents due to defects in or failure of some part of the locomotive or tender.

	1923	*1922*	*1921*	*1920*
Number of derailments (1)	38	22	8	7
— killed	4	5	...	7
— injured	157	61	30	18

During the year numerous accidents were investigated where welds made by the fusion or autogenous process were involved. The investigations fully support the position previously taken that this process has not reached a state of development where it can safely be depended upon in boiler construction and repair where the strain to which the structure is subjected is not carried by other construction, nor in firebox crown sheet seams where overheating and failure are liable to occur, or on any part of the locomotive or tender subject to shock or strain where, through failure, accident and injury might result.

Numerous accidents have occurred due to the failure of autogenously welded seams and cracks in the boiler back head. One fatal accident of this nature occurred where an autogenously welded crack 21 1/2 inches long in the boiler back head failed while the locomotive was hauling a passenger train, resulting in death to the engineer and the serious injury of the fireman. The scalding water and steam escaping through the rupture compelled the engineer to leave the cab without being able to close the throttle or apply the brakes in the usual way. The engineer and fireman climbed out of and around the left side of the cab to he running board and to the front end of the locomotive, where the angle cock was opened and the brakes applied.

Accidents caused by defective grate-shaking apparatus increased from 48 during the preceding year to 138 during the present year, an increase of 187 %. The major portion of these accidents were caused by the shaker bar not having a proper fit on the fulcrum lever. Since it is impossible to avoid the changing of shaker bars from one locomotive to another, each carrier should adopt a standard whereby shaker bars are made

(1) Only derailments reported by carriers as being caused by defect in or failure of parts of the locomotive or tender were investigated or counted.

interchangeable with a proper fit on the fulcrum levers.

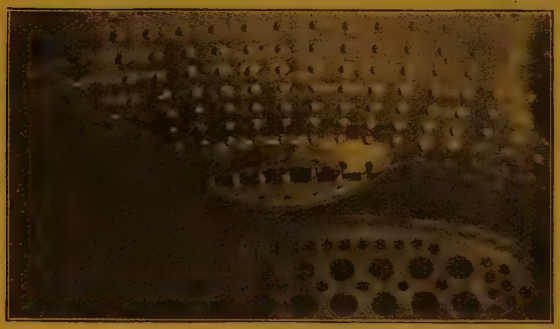

Fig. 1. — Low water caused autogenous weld to open up for 36 inches.

Fig. 2. — Overheated crown sheet pulled away from 238 radical stays and pocketed 17 1/2 inches without other material damage.

Accidents due to the failure of injector steam pipes increased from nine during the preceding year to 40 during the year. A majority of these accidents were due to the injector steam pipe pulling out of the brazing collar due to defective workmanship and to breakage caused by weak, light construction and to defective material. In many instances the failure of injector steam pipes was contributed to by the injector not being properly fastened so as to relieve the steam pipe from the weight and vibration of the injector and its connections.

Fig. 3. — Two broken staybolts with heads welded over and one with hole plugged.

Accidents which reflect the general condition of driving gear, running gear, etc., increased materially. For instance, main and side rod accidents increased from 23 to 53; valve-gear accidents increased from 18 to 59; and accidents due to failure of reversing gear increased from 53 to 100.

During the year 230 applications were filed for extension of time for removal of flues. Investigation disclosed that in 34 cases the condition of the locomotives was such that no extension could be granted. Fourteen were in such condition that the full extension requested could not be authorized, but an extension for a shorter period was allowed. Fourteen extensions were granted after defects disclosed had been repaired. Thirty applications were withdrawn and the remaining 133 were granted.

There were filed 5 076 specification cards and 11 187 alteration reports necessary in determining the safe working pressure and other required data for the boilers represented. These cards and reports were analyzed and corrective measures taken with respect to numerous discrepancies which were found. It was required that many older and weak boilers be reinforced or the working pressure reduced.

In two instances appeals were taken from the decision of inspectors and after careful consideration of existing conditions the appeals were partially sustained and partially dismissed. The decisions of these inspectors were technically in error, but practically correct.

The recommendations for betterment of service made at the close of the report were the same as last year. The following is a brief summary of these recommendations :

Persons killed and injured, classified according to occupations.

—	*1923*		*1922*		*1921*		*1920*	
	Killed.	Injured.	Killed.	Injured.	Killed.	Injured.	Killed.	Injured
Members of train crews :								
Engineers	19	484	11	213	15	237	16	272
Firemen	16	597	10	277	25	360	20	404
Brakemen	12	137	7	66	13	64	9	77
Conductors	1	35	...	25	2	20	2	19
Switchmen	2	32	1	13	3	15	4	19
Roundhouse and shop employees :								
Boiler makers	3	19	1	10	1	7	2	9
Machinists	2	14	...	9	1	3	1	20
Foremen	1	6	...	1	1	3	...	3
Inspectors	...	2	..	2	...	5	...	1
Watchmen	1	6	...	3	...	4	4	3
Boiler washers	1	9	...	1	...	7	..	13
Hostlers	...	31	...	10	..	8	...	13
Other round house and shop employees.	4	29	1	15	1	25	3	30
Other employees	4	36	2	23	2	16	4	26
Non-employees.	6	123	...	41	...	21	1	7
Total.	72	1 560	33	709	64	800	66	916

Accidents and casualtfes resulting from failures of locomotives and tenders and their appurtenances.

PART OF APPURTENANCE.	*Year ended 30 June*								
	1923			*1922*			*1921*		
	Accidents.	Killed.	Injured.	Accidents.	Killed.	Injured.	Accidents.	Killed.	Injured.
Air reservoirs	6	...	7	3	...	3	1	...	1
Aprons	8	...	8	11	...	11	16	...	16
Arch tubes	12	2	17	4	...	5	5	...	5
Ash-pan blowers	19	...	19	7	...	7	5	...	5
Axles	6	...	7	5	...	17	5	..	6
Blow-off cocks	28	..	29	16	...	16	14	...	14
Boiler checks	12	..	12	4	...	4	7	1	7
Boiler explosions :									
A. Shell explosions	...	..	...	1	...	1	...	...	...
B. Crown sheet; low water; no contributory causes found	19	24	27	13	15	23	20	19	26
C. Crown sheet; low water; contributory causes or defects found	34	15	56	14	6	27	33	24	52
D. Firebox; defective stay bolts, crown stays, or sheets	4	2	5	5	1	5	1	2	...
Brakes and brake rigging	27	1	56	10	2	24	6	...	6
Couplers	25	1	27	21	...	23	11	1	13
Crank pins, collars, etc.	12	...	13	10	...	10	6	3	8
Cross heads and guides	10	...	10	4	...	4	4	1	4
Cylinder cocks and rigging	1	..	11	3	...	3	4	...	4
Cylinder heads and steam chests	8	...	8	3	...	3	6	...	6
Draft appliances	13	...	14	6	...	9	8	...	9
Draw gear	16	2	16	7	...	7	8	1	8
Fire doors, levers, etc.	26	...	26	2	...	2	8	...	8
Flues	41	...	59	28	..	32	32	1	35
Flue pockets	2	...	5	1	1	...	1	1	...
Foot boards	36	1	35	11	1	10	8	3	5
Gage cocks	...	...	...	2	...	2	...	...	...
Grease cups	6	1	6	3	...	3	7	...	7
Grate shakers	138	...	138	49	...	49	85	...	85
Handholds	34	2	32	12	1	11	19	...	20
Headlights and brackets	8	...	8	2	...	2	8	2	6

Accidents and casualties resulting from failures of locomotives and tenders and their appurtenances.

(*Continued.*)

PART OF APPURTENANCE.	*Year ended 30 June*								
	1923			*1922*			*1921*		
	Accidents.	Killed.	Injured.	Accidents.	Killed.	Injured.	Accidents.	Killed.	Injured.
Injectors and connections (not including injector steam pipes)	33	...	33	21	..	24	15	2	13
Injector steam pipes	40	...	46	9	...	9	15	...	17
Lubricators and connections	22	..	22	9	...	9	12	...	12
Lubricator glasses	10	...	10	3	...	3	3	...	3
Patch bolts	3	...	3	...	...	...	...	...	...
Pistons and piston rods	14	1	13	6	...	6	3	..	3
Plugs, arch tube and washout	18	3	27	12	1	19	15	...	18
Plugs in firebox sheets	...	...	...	2	...	3	2	...	2
Reversing gear	100	...	100	53	...	53	65	...	65
Rivets	5	...	8	...	..	...	4	...	5
Rods, main and side	53	3	57	23	..	27	18	..	21
Safety valves	...	...	...	...	...	...	...	...	...
Sanders	4	...	4	2	...	2	...	...	...
Side bearings	..	..	..	1	...	1	...	..	...
Springs and spring rigging	25	2	25	10	1	9	3	...	3
Squirt hose	67	...	69	54	...	54	82	...	82
Stay bolts	7	...	8	6	...	8	...	..	..
Steam piping and blowers	19	..	19	9	...	11	9	...	9
Steam valves	16	1	16	6	...	6	11	...	12
Studs	6	...	8	7	...	8	7	...	7
Superheater tubes	10	..	15	...	..	...	1	...	2
Throttle glands	1	...	1	1	..	1	...	..	...
Throttle leaking	6	...	6	3	1	2	3	...	3
Throttle rigging	19	2	19	5	..	5	1	...	1
Trucks, leading, trailing or tender	25	5	101	11	2	25	6	...	8
Valve gear, eccentrics and rods	59	2	59	18	...	18	10	...	10
Water glasses	35	...	35	19	...	19	25	..	25
Water-glass fittings	7	...	7	6	...	6	2	...	2
Wheels	10	1	19	8	1	7	4	1	4
Miscellaneous	170	1	179	61	...	61	91	2	117
Total	1 348	72	1 560	622	33	709	735	64	800

That the act of 17 February 1911, be amended to provide for not less than 50 additional inspectors and increased compensation adequate to carry out the purpose of the law.

That all coal-burning locomotives have mechanically operated fire doors so constructed that they may be operated by pressure of the foot on a pedal or other suitable device.

That a power reverse gear be applied to all locomotives.

That all locomotives be provided with an automatic, power-operated bell ringer.

That the cab of all locomotives not equipped with front doors or windows of such size as to permit of easy exit, have a suitable stirrup or other step and a horizontal handle on each side approximately the full length of the cab.

That all locomotives where there is a difference between the readings of the gage cocks and water glass of 2 inches or more under any condition of service, be equipped with a suitable water column, to which shall be attached three gage cocks and one water glass, also one water glass with not less than 6 inches clear reading on the left side or back head of the boiler.

MISCELLANEOUS INFORMATION

[621 .132.6 (.42)]

1. — 4-6-4 tank engine, London Midland & Scottish Railway.

Figs. 1 and 2, pp. 574 and 575.

The London Midland & Scottish Railway are building, in their Horwich Works, ten 4-6-4 tank engines of a new type and of which we give a drawing taken from the *Railway Gazette* (fig. 1).

The engines are intended for working heavy suburban traffic and also to replace, in certain cases, the 4-6-0 express locomotives, the main features of which are incorporated in them. They have, for example, four cylinders arranged for single expansion working, the inside cylinders are coupled to the leading axle by means of connecting rods 6 ft. 8 in. in length the outside cylinders acting on the second axle, the connecting rods being 11 feet long. The four valves are operated by means of two sets of Walschaert's valve gear situated outside the frames.

The piston valves are provided with pressure release valves designed by Mr. Hughes, chief mechanical engineer of the company, in which steel balls are held on their seatings by the steam pressure in the steam chest, and which are forced off their seats should an excess of pressure occur in the cylinder.

The cylinders are cast in three pieces, the two inside cylinders and their steam chests forming a single casting.

A special feature of these engines is the superheater, which has been designed by Mr. Hughes, and which has already been used on 0-8-0 locomotives. This superheater, which is known as the « Horwich Superheater » differs from those in general use, in that the header instead of being in one single casting with two chambers, one for saturated steam and the other for superheated steam, is made up of one top casting receiving the saturated steam and two bottom castings which receive the superheated steam. This arrangement, which has been given the name of the « top and bottom header » superheater, has the advantage in that any chance of transmission of heat from the superheated to the saturated steam is done away with. The large smoke tubes are placed in two vertical rows on each side of the centre line of the boiler; the two bottom headers are bolted directly to the cylinders, thus doing away with any external steam pipe. The drawing figure 2 shews this superheater as fitted to the 0-8-0 engines.

The principal dimensions of the 4-6-4 locomotives are as follows :

Cylinders (4) diameter	16 1/2 inches.
Piston stroke	26 inches.
Diameter of coupled wheels	6 ft. 3 in.
— of bogie wheels	3 ft. 0 3/8 in.
Wheelbase bogie	7 feet.
— rigid	13 ft. 7 in.
— total	40 ft. 4 in.
Boiler, length between tube plates	14 ft. 8 in.
— diameter inside front end	5 ft. 7 in.
— height of centre from rail.	8 ft. 11 in.
Boiler, heating surface (water side) :	
Tubes (large and small)	1 817 square feet.
Firebox	180 — —
Total.	1 997 square feet.

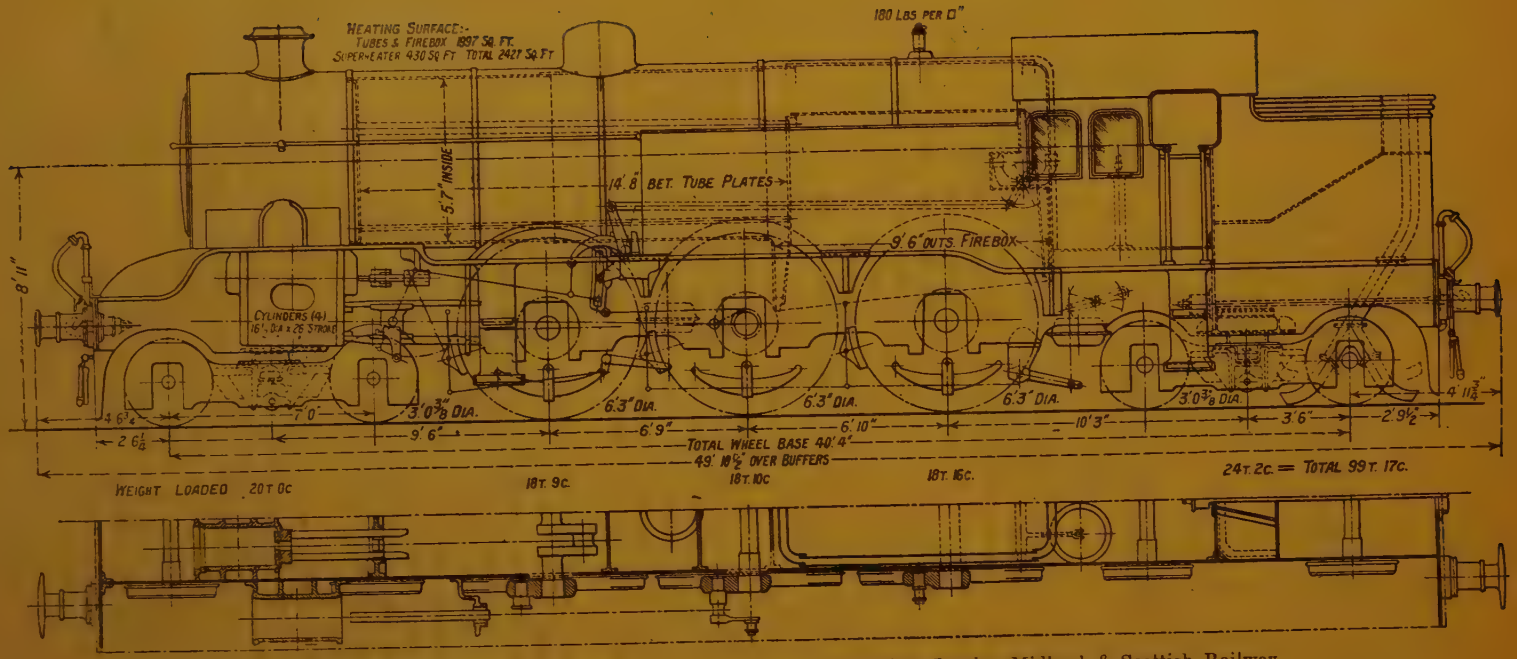

Fig. 1. — 4-6-4 four-cylinder tank engine for express passenger trains, London Midland & Scottish Railway.

Superheating surface (steam side)	430 square feet.	Adhesion weight (in working order)	55 t. 15 cwt.
Grate area	29.6 — —	Total weight	99 t. 17 cwt.
Working pressure	180 lb. per square inch.	Water capacity	2 000 gallons.
Tractive effort (at 85 % of boiler pressure	28 879 lb.	Coal capacity	3 1/2 tons.

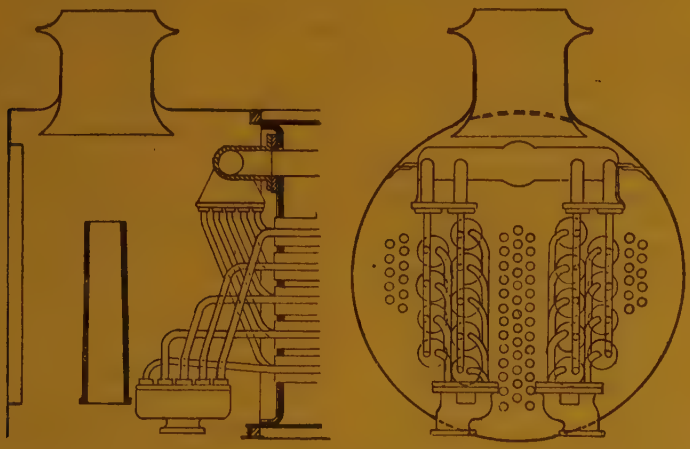

Fig. 2. — « Horwich » superheater as applied to 0-8-0 locomotives.

The length of run is limited only by the coal capacity, the engine being fitted with water pick-up gear arranged for use when running in either direction.

E. M.

[621 .432.5 (.73)]

2. — Chesapeake & Ohio 2-8-8-2 simple Mallet.

Figs. 3 to 8, pp. 577 to 581.

(From the *Railway Mechanical Engineer* and the *Railway Review*.)

One of the most interesting of recent locomotive designs is that of the Chesapeake & Ohio 2-8-8-2 type single expansion Mallets, of which 25 are being delivered by the American Locomotive Company. The Chesapeake & Ohio has employed Mallet locomotives for a number of years, but these have been of the 2-6-6-2 type, 45 of which were placed in service during the period of the United States Railroad Administration.

The tunnels and restricted clearances on the Chesapeake & Ohio have prevented the use of the heavier type articulated locomotives of the usual design. The problem presented was therefore that of designing as powerful a locomotive as possible without exceeding the clearance limitations. As space was not available for compound cylinders, the very unusual practice of making all four cylinders high-pressure, single-expansion was adopted. While the almost universal practice in Mallet locomotives is to use double expansion, the Pennsylvania has had in operation for several years one large 2-8-8-0 simple Mallet with limited cut-off and a few small simple Mallets have been built at various times for export or industrial service

This is the first instance, however, in which any considerable number of large articulated locomotives of the single-expansion type have been built.

Another important consideration, which led to the unusual design of these locomotives, was the desire to operate them at higher running speeds than experience has shown to be practical for heavy compound articulated locomotives. By increasing both train loads and operating speeds, the maximum increase in traffic capacity could be obtained.

The new Chesapeake & Ohio engines, known as Class H-7, or Chesapeake type, are remarkable for their power, large boilers and compact, carefully worked out design. The maintenance of Mallet locomotives used in heavy service has always been considerable of a problem. This has been met on the Chesapeake & Ohio by organizing special repair gangs at all terminals and giving prompt attention to the features requiring attention without postponing work until the locomotive was removed from service for extensive repairs. Having had an extended experience with a considerable number of Mallet locomotives, it very properly followed that in making an entirely new design, careful attention was given to details so as to reduce attention and maintenance expenses to the lowest point possible.

These locomotives are practically two Consolidation engines with only one boiler. They measure 109 ft. 3 3/8 in. from the front of the engine to the rear of the tender and have a total weight of 775 000 lb. in working order with the tender loaded. The distribution of the weight is as follows : 32 000 lb. on the front truck; 251 500 lb. on the forward set of drivers; 239 500 lb. on the second set of drivers, and 42 000 lb. on the trailing truck, making the total weight of the engine alone 565 000 lb. The engine alone is 70 ft. 1 5/8 in. long. The driving wheel base of each unit is 15 ft. 9 in., the engine wheel base is 58 ft. 1 in., and the total wheel base of the engine and tender is 98 ft. 3/8 in. All four cylinders are 23 inches in diameter with a 32-inch stroke. The driving wheels are of 57 inch diameter and the rated tractive force of the locomotives is 103 500 lb. They are designed to operate on 20° curves and on grades up to 1 1/2 %.

The boilers are of an exceedingly interesting design and are the longest ones ever built at the Schenectady plant of the American Locomotive Company. The length from the front of the smoke box ring to the back end of the mud ring is 56 ft. 11 1/8 in. The shell of the boiler, which is of the straight top type, consists of five courses, not including the smoke box or the firebox wrapper sheet. The inside diameter of the first course is 92 inches and the outside diameter of the course back of the dome is 104 inch diameter. The photograph of the locomotive as well as the drawings show that every available inch was used without exceeding the restricted clearances allowable. The dome is only 5 1/2 inches high and the stack extension is but 11 1/2 inches.

The provision of ample boiler capacity is one of the conspicuous features of the design. Upon sufficient steaming capacity depends the ability to maintain the speed with trains which the locomotive was designed to haul. The wide firebox is 204 1/8 inches long and 96 1/4 inches wide. It is fitted with a Gaines firewall and has a grate area of 112.9 square feet, 169 inches by 96 1/4 inches, for burning soft coal. There is also a combustion chamber 69 inches long. Arch tubes are not used, although provision was made for their future application should this be found advisable. There are 278 tubes, 2 1/4 inch diameter and 60 flues, 5 1/2 inch diameter, the length being 24 feet. There is 6 443 square feet of evaporative heating surface, 467 square feet being in the firebox and 5 976 square feet in the tubes and flues. The heating surface of the 60 units of the type A superheater is 1 885 square feet. According to Cole's proportions, the rated cylinder horsepower is 3 902 H. P. and that of the boiler 3 677 H. P., or 94.2 %. This does not include any allowance for the effect of the two Elesco feedwater heaters, with which all these locomotives are equipped.

The firing is done with a Duplex stoker, which is here called on to perform what is probably the most strenuous work ever demanded of it. The estimated coal consump-

Fig. 3.

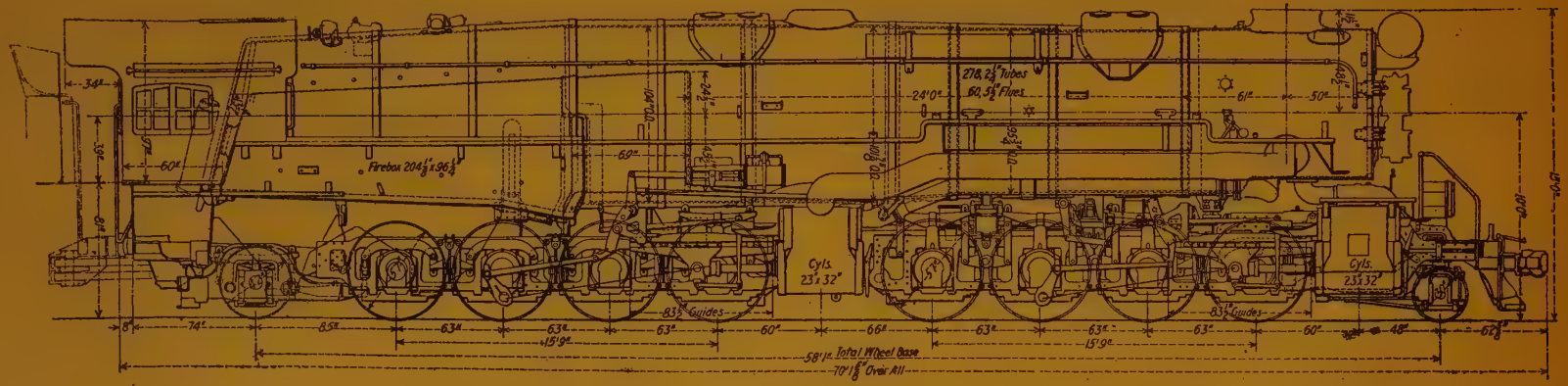

Fig. 4.

Figs. 3 and 4. — The Chesapeake & Ohio is receiving 25 of these powerful simple Mallet locomotives.

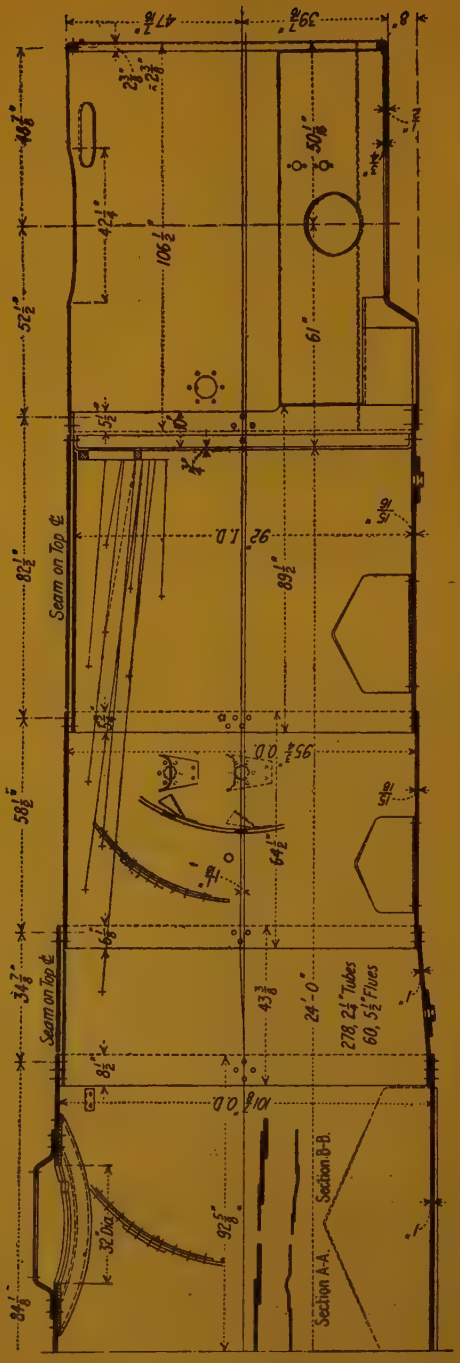

Fig. 5. — Front end of boiler for Chesapeake & Ohio 2-8-8-2 Mallet locomotive.

tion at the rate of 3 1/4 lb. per cylinder horsepower hour is 12 682 lb., or at the rate of 112.9 lb. per square foot of grate per hour.

The ash pan is of the self-cleaning hopper type and so designed that it can be taken down without removing the trailing wheels. It is built of 1/4-inch steel and provision is made for washing down the sides while running. The air space through the ash pan dampers is 90 % of the gas area through the tubes and flues.

There are many interesting features about the boiler design, some of which are quickly apparent from an examination of the drawings. There is a large amount of exceptionally fine welding on the boilers. The welded joints include the long seam between the crown sheet and the firebox side sheets and also between the combustion chamber and the firebox. At the joint the sheets are beveled 1/8 inch and lapped 1/2 inch with a weld on both sides, as shown in the detail drawing. At the junction of the combustion chamber and the firebox, a corrugation is provided, as shown in the drawings, this to better care for the expansion at this point.

The design of the cylinders for these engines is rather unusual in that instead of parting the back pair on the center line as is the common practice, one cylinder casting is 12 inches wider than the other, which was done to provide room for the steam supply pipe between the front back sets of cylinders. The superheated steam from the boiler is supplied to the two sets of cylinders through a series of connected pipes. The steam first passes through the usual set of two steam pipes inside the smoke box, into two other steam pipes 9 5/8 inches in diameter, one on each side of the engine, running parallel with an outside of the boiler, and connecting the smoke box steam pipes with the valve chambers of the back set of cylinders. It next passes through a passage in the form of a Y, in the back cylinder castings, into another steam pipe directly connecting the front and back sets of cylinders. This pipe is provided with swivel joints at each end and is located between the driving wheels of the engine just above the driving axles. From this pipe the steam passes through another passage in

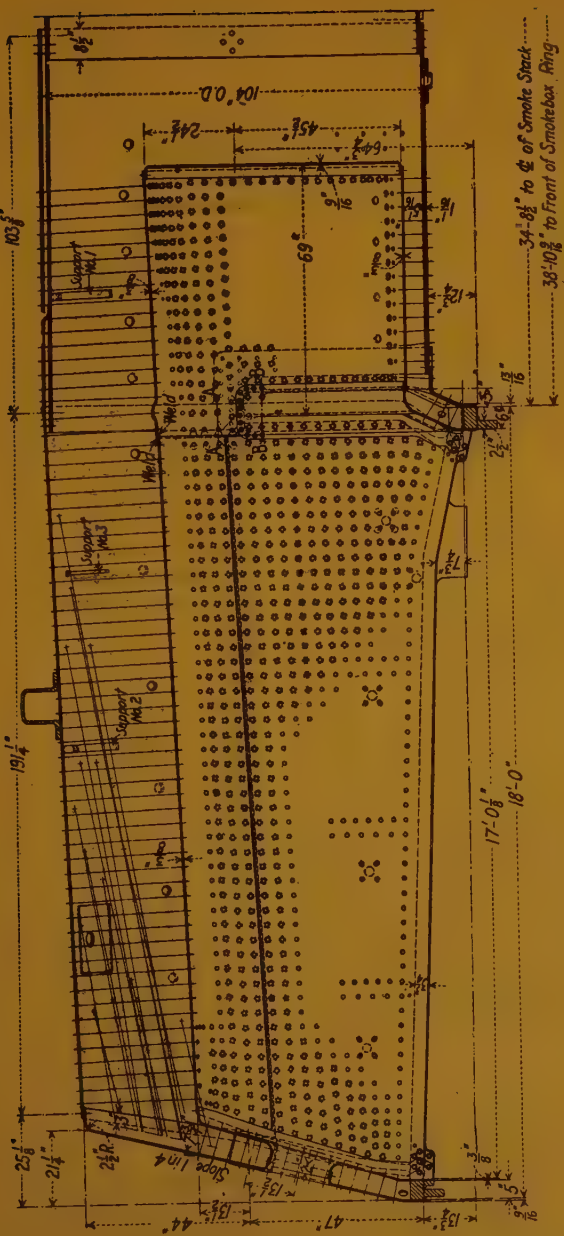

Fig. 6. — Firebox end of boiler for Chesapeake & Ohio 2-8-8-2 Mallet locomotive.

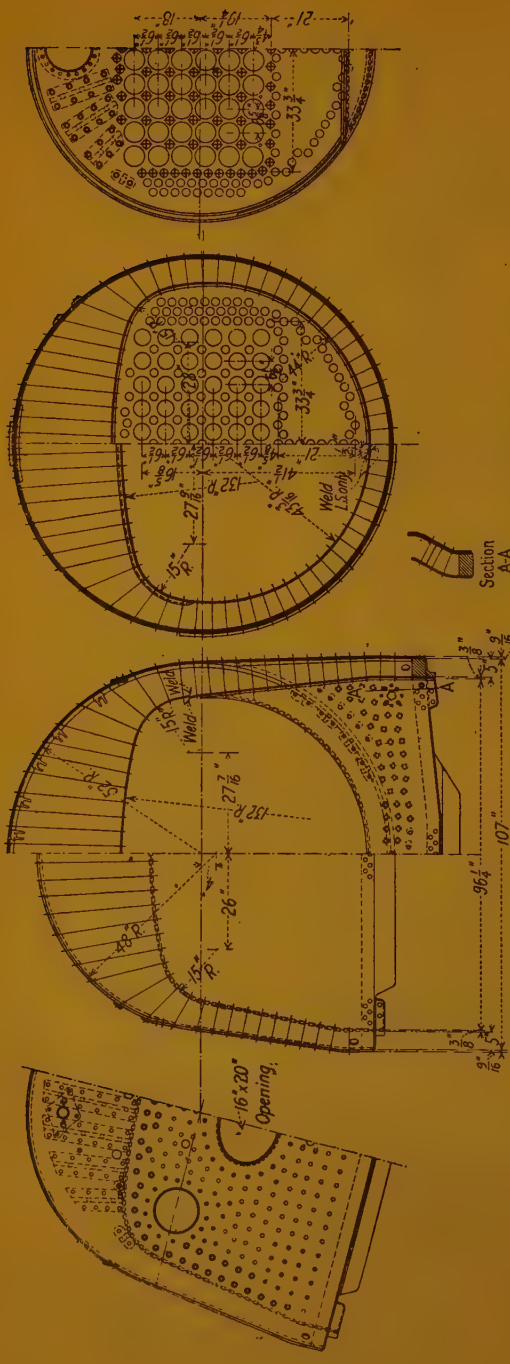

Fig. 7. — Back view and cross-sections of the Chesapeake & Ohio Mallet boiler.

the form of a Y, in the front cylinder castings, into the valve chambers of the front set of cylinders. In order to reduce steam leaks and to prevent the loss of heat all of the steam pipes are provided with either swivel joints or a form of sliding connection and are covered with insulating material as well as sheet metal jackets, while Okadee drain valves are provided to permit the condensed steam to escape from the pipes.

Two exhaust pipes, one for each cylinder, running parallel with and under the steam supply pipes, connect the back cylinders with the exhaust nozzle in the smoke box. Two other exhaust steam pipes are provided for connecting the front cylinders with the exhaust nozzle, and as was the case with the steam supply pipes, these exhaust pipes are also provided with suitable swivel joints or sliding connections as required to provide a means of keeping the pipe joints tight when the engine is on curved track.

It will be noticed in the illustrations of the front end arrangement that two separate exhaust nozzles were originally provided, one for each set of cylinders, and a separate passage was provided in each nozzle for the exhaust steam from each of the four cylinders, but since the engines have been placed in service these exhaust nozzles have been redesigned, and instead of having four openings, two in each exhaust nozzle, the engines now have two exhaust stands with but one opening 5 1/4 inches in diameter in each nozzle. This change was made by the mechanical department of the road in order to reduce the amount of fuel and water consumed and has proved so satisfactory that it is possible that the exhaust nozzles will eventually be increased to 6 inches in diameter, which is considered quite large for cylinders 23 inches in diameter.

The rated tractive force at 85 % with the four 23-inch by 32-inch cylinders, 57-inch driving wheels and 205 lb. steam pressure, is 103 500 lb. The steam is controlled by 14-inch piston valves operated by Walschaerts valve gear. The reverse gear is the Alco, Type E. The cylinders are fitted with Mellin by-pass valves and vacuum relief valves.

Carbon-vanadium steel is used for the main

and side rods, the crank pins, the piston rods, the wrist pins, the valve motion parts and also for the leading and trailing truck axles as well as the driving axles. The piston is of forged steel. The main driving axles, which have 11 1/2 inches by 13 inches journals and the other driving axles, which have 11 inches by 13 inches journals, are all hollow bored. The frames are of vanadium cast steel.

The leading truck is of the Commonwealth « Economy » constant resistance type. The trailing truck is of the Delta type. Engine truck, trailing truck and tender truck wheels are of forged steel.

The throttle in the dome is of the American Locomotive Company's design, top-lift type with a pilot valve. The dry pipe is 9 1/2 inches inside diameter, 1/4 inch thick. An unusual feature is that of the slipping throttle with a choke resembling a stove pipe damper in the rear unit exhaust pipes and the front unit steam pipe. These are operated by an air cylinder mechanism, independently controlled by three-way air valves located in the cab.

The smoke box front end is made in three sections. The feedwater heater is mounted on the top section. The lower sections are divided vertically. An 8 1/2-inch cross-compound air compressor is mounted on each of these sections, which are arranged to swing out with the air compressor on Okadee hinges. A center plate is also provided which permits of access to the front end without disturbing the air compressors or the feedwater heater.

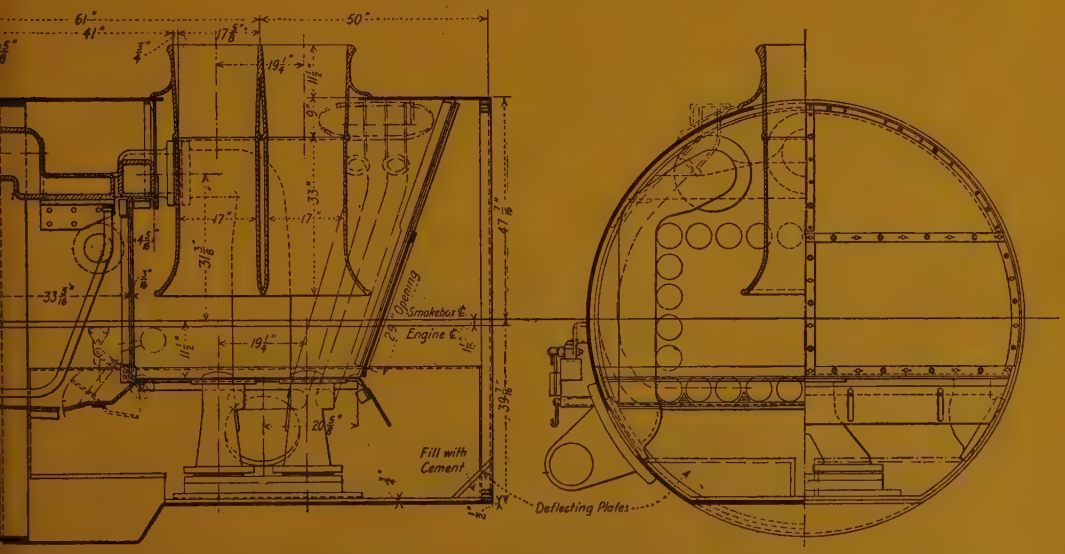

Fig. 8. — Smoke box construction showing design of double stack, one for each engine unit.

The headlights, Pyle-National Type K-2, operated by a turbo-generator, are placed down near the bumper beams.

These locomotives will be operated through a number of tunnels, some of which are quite long. A noteworthy feature is the provision that has been made for the comfort of the enginemen while passing through these tunnels. As a result of extended tests made by the mechanical department of the Chesapeake & Ohio, assisted by experts from the Bureau of Mines, Department of the Interior, two steel fan blowers, Buffalo Forge Company's size No. 2, were installed under the cab deck, one on each side. They are driven independently by Pyle-National, Type K, headlight turbines. The

inlet air pipes lead back to the space between the engine and tender with the discharge pipes leading up into the cab. This arrangement provides a stream of comparatively pure air and at the same time reduces the temperature in the cab. As a further precaution, three gas masks are provided. These receive their air supply from the main reservoir. Moreover the back boiler head is lagged down to the deck and all cab steam pipes covered with Unarco Asbestos Insulate.

The tender is of the Vanderbilt type and holds 12 000 gallons of water and 15 tons of coal. It is mounted on a single-piece, cast steel frame. The trucks are of the four-wheel type with Andrew's cast steel side frames and cast steel bolsters. The tender coupler is a Type D with 6-inch by 8-inch shank and 5 1/4-inch butt. The draft gear is a Miner A-18-S-2, with Farlow two-key attachments. A Franklin unit safety drawbar connects the locomotive and tender.

Some difficulty was experienced in finding a space for the main reservoirs of the Westinghouse air brake system. This was finally taken care of by using three reservoirs, one 14-inches by 144-inches on the right-hand side, one 14-inches by 108-inches on the left-hand side and one 14-inches by 120-inches near the top of the boiler. The total reservoir capacity is 70 696 cubic inches.

Among the specialties the following not previously mentioned, are included: Hancock nonlifting Type K injectors having a capacity of 9 000 gallons per hour, and accompanied by 3-inch check valves; three 3 1/2-inch Consolidated safety valves, two open and one muffled; Okadee 2-inch Type FH blow-off cocks; Okadee WG 13 water gages; Franklin grate shaker and No. 8 firedoor; Nathan eight-feed lubricator; Graham-White sanders; Detroit flange oilers; United States Metallic packings for piston rods and valve stems; Hunt-Spiller gun metal bushings for cylinders and valve chests; and Barco flexible joints in air lines between engine and tender and screw type flexible joints in main reservoir pipes.

The general dimensions and proportions of these interesting locomotives are given in an accompanying table.

Table of dimensions, weights and proportions.

Railroad	Chesapeake & Ohio.
Builder	American Loco. Co.
Type of locomotive	2-8-8-2 Simple.
Service	Freight.
4 cylinders, diameter and stroke	23 in. by 32 in.
Valve gear, type	Walschaerts.
Valves, piston type, size	12 inches.
Maximum travel	6 —
Outside lap	1 —
Exhaust clearance	0
Lead in full gear	1/8 inch.
Weights in working order:	
On drivers	491 000 lb.
On front truck	32 000 lb.
On trailing truck	42 000 lb.
Total engine	565 000 lb.
Tender	210 000 lb.
Wheel bases:	
Driving, each	15 ft. 9 in.
Rigid, each	15 ft. 9 in.
Total engine	58 ft. 1 in.
Total engine and tender	98 ft. 3/8 in.
Wheels, diameter outside tires:	
Driving	57 inches.
Front truck	30 —
Trailing truck	42 —
Journals, diameter and length:	
Driving, main	11 1/2 inches by 13 inches.
Driving, others	11 — by 13 —
Front truck	6 1/2 — by 12 —
Trailing truck	8 — by 14 —
Boiler:	
Type	Straight ton.
Steam pressure	205 lb.
Fuel	Bituminous coal.
Diameter, first ring, inside	92 inches.
Firebox, length and width	204 1/8 in. by 96 1/4 in.
Height mud ring to crown sheet, back	60 1/2 inches.
Height mud ring to crown sheet, front	89 1/4 —
Combustion chamber length	69 —
Tubes, number and diameter	278 — 2 1/4 —
Flues, number and diameter	60 — 5 1/2 —
Length over tube sheets	24 feet.
Grate area 169 in. by 96 1/4 in.	112.9 square feet.

Heating surfaces :

Firebox and combustion chamber	467	square feet.	
Tubes	3 912	—	—
Flues	2 064	—	—
Total evaporative	6 443	—	—
Superheating	1 885	—	—
Combined evaporative and superheating	8 328	—	—

Tender :

Style	Cylindrical.
Water capacity	12 000 gallons.
Coal capacity	15 tons.
Trucks	Four-wheel.

General data estimated :

Rated tractive force, 85 %	103 500 lb.
Cylinder horsepower (Cole)	3 902 H. P.
Boiler horsepower (Cole) (est.) (1)	3 677 H. P.
Speed at 1 000 feet piston speed	31.8 miles per hour.
Steam required per hour	81 162 lb.
Boiler evaporative capacity per hour (1)	76 472 lb.
Coal required per hour, total	12 682 lb.
Coal rate per square foot grate per hour.	112.9 lb.

Weight proportions :

Weight on drivers ÷ total weight engine, %	86.9
Weight on drivers ÷ tractive force	4.91
Total weight engine ÷ cylinder H. P.	147.1
Total weight engine ÷ boiler H. P.	156.1
Total weight engine ÷ combined heating surface	67.9

Boiler proportions :

Boiler H. P. ÷ cylinder H. P., % (1)	94.2
Combined heating surface ÷ cylinder H.P.	2.13
Tractive force ÷ combined heating surface.	12.42
Tractive force × diameter drivers ÷ combined heating surface	708
Cylinder H. P. ÷ grate area	34.5
Firebox heating surface ÷ grate area	4.40
Firebox heating surface, % of evaporative heating surface	7.72
Superheating surface, % of evaporative heating surface	29.25

[621 .132.6 (.44)]

3. — Paris-Orleans condensing locomotive,

By H. LEFLOT,

INSPECTOR OF EQUIPMENT, PARIS-ORLEANS RAILWAY.

Figs. 9 and 10, p. 584.

(*Railway Mechanical Engineer.*)

The Paris-Luxembourg line to Sceaux and Limours runs well into the City of Paris and passes through a tunnel, a little over a mile long, situated between the stations of Paris-Luxembourg and Paris-Denfert. When the line was built it was apparent that certain measures must be taken to avoid inconvenience to the passengers from the escaping smoke and steam of the locomotive during the passage through the tunnel.

Black smoke could be done away with by special care in the control of the fire, but the question of the exhaust steam remained. To overcome this trouble, the Paris-Orleans railroad equipped a locomotive with an arrangement for condensing in the water tank as much of the exhaust steam as possible.

On the first locomotive equipped with condensing apparatus the boilers were fed by injectors. Upon reaching the end of the tunnel at Denfert, it was found necessary to partly empty the tanks and replace the hot water by cold water taken at the water crane, in order to obtain a sufficiently low temperature to secure reliable action of the injectors.

Furthermore, to insure a supply of water to the boiler during the time the condensing apparatus was in operation, a supplementary

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(1) No allowance for feedwater heaters included.

cold water tank, having a capacity of 106 gallons, was employed. This tank was so arranged that it could be placed in communication with the ordinary tanks or held in reserve until needed.

This method of operation wasted a considerable amount of water and fuel and caused an undesirable loss of time between stations only a short distance apart, where quick service was important.

The original locomotives having become incapable of making the running time with the increasing traffic that had to be handled, it was decided to replace them by more powerful tank locomotives of the 2-8-2 type fitted with superheaters. At this time, in order to do away with the inconveniences mentioned, we developed a new condensing apparatus and applied two Worthington pumps for feeding the boiler. This permitted using the water in the tank at all times no matter what the temperature might be.

Description of the condensing apparatus.

As will be noted from the drawings, this apparatus is a sort of surface condenser. It consists of copper exhaust pipes C, brass pipes, E, for condensing the exhaust or discharging above the water in the tank any steam that has not been condensed, also copper pipes, G, which permits the final escape to the atmosphere of the non-condensed steam if any still remains.

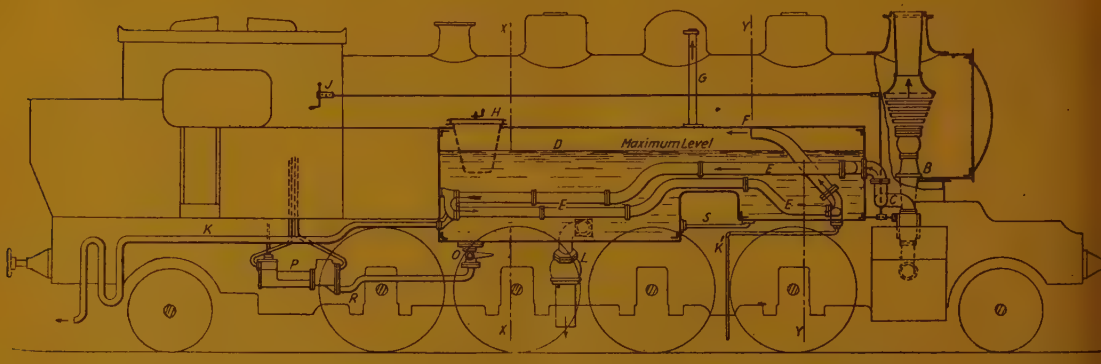

Fig. 9. — Elevation showing water tank and condensing apparatus.

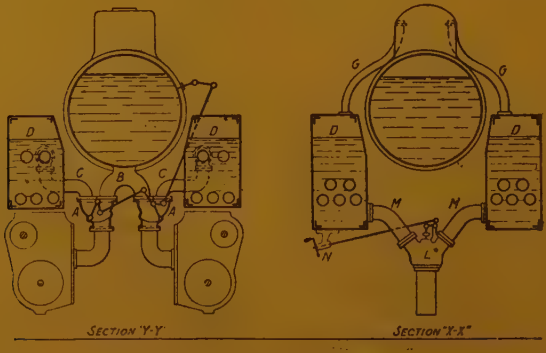

Fig. 10. — Cross sections.

The waste pipes are two in number; the main waste pipe, K, terminates underneath the coal box and has at the end a double elbow, which forms a trap to prevent the escape of the non-condensed steam in the pipe E. The other pipe, K^1, discharges the water of condensation between the first and second pair of driving wheels.

To permit the utilization of the apparatus at will, a control valve, A, is placed in the exhaust pipe of each cylinder. Both of these valves are operated by the handle, J, located conveniently for the engineman. This permits the directing of the exhaust steam into the water tanks or to the atmosphere by way of the stack.

The two water tanks, D, are connected by the cross-over pipe, M. They can be emptied by a valve, L, operated by the handle, N, shown in the cross section. There is also a pipe, S, connecting the front and the back portion of the tank to secure a circulation of water and to divide the heat evenly throughout the tank.

Operation of the devise.

By suitably adjusting the valves, A, by the handle, J, communication is established between the exhaust pipe and the condensing apparatus. The exhaust steam is then directed into the pipes, E, and there partly condensed, while the remainder passes out by the top extension, F, to be condensed by contact with the surface of the water in the tanks. Any surplus of steam not condensed escapes in the atmosphere by the vent pipe, G, and the water of condensation passed away by the waste pipes, K and K^1, as shown on the elevation drawing of the locomotive.

By means of cocks, suitably located, the engineman may divert the exhaust steam from the feedwater pumps either to the atmosphere or to pipes leading to the water tanks. The exhaust steam from the air compressor is piped to one of the locomotive exhaust passages, A, and follows the same course as the exhaust from the main engine cylinders.

The cover, H, of the water tank is kept tightly closed to avoid the escape of the steam and projection of water on to the tracks. The volume of water contained in the tanks at the maximum level, which is indicated by a gage cock placed on a partition on the side of the tank, is 212 cubic feet, or 1 585 gallons. The maximum level is at 13 1/2 inches from the top of the reservoir. Should this level be exceeded and a surge of water caused by the motion of the locomotive reach the top of the condensation pipe, the surplus would pass off the waste pipes, K and K^1, following a course the reverse of the one taken by the condensed steam outlined in the preceding paragraph.

Summary.

It is apparent from what has been stated that the exhaust steam condensing apparatus of the new tank locomotive on the line between Paris and Limours has succeeded in solving the particular problem of the suppression and the escape of the exhaust steam to the atmosphere during the passage through the tunnel.

Economy of fuel was not the object aimed at. There is no doubt, however, that the condensing apparatus results in some saving due to the heating of the feedwater, but this saving is small inasmuch as the condensing apparatus functions only between the two stations of Denfert and Luxembourg, less than a mile apart. When it functions and all the exhaust steam is sent into the water tanks, the draft is almost completely extinguished and the use of the blower becomes necessary. This reduces the economy resulting from the recovery of the heat contained in the exhaust steam from the cylinders.

[625 .245 (.73)

4. — New transformer cars for the New York New Haven & Hartford Railroad.

Fig. 11, p. 587.

(*Railway Review.*

The New York New Haven & Hartford Railroad has recently placed in service two 70-ton capacity steel underframe transformer cars built by the Standard Steel Car Co. at their Butler (Pa.), plant. The cars have been designed to carry a load of 150 000 lb. uniformly distributed over a length of 24 feet at the center of the car. The sizes of the underframe members have been so determined as to allow the fibre stress not to exceed 16 000 lb. per square inch in the stills and cross ties and 15 000 lb. in the bolsters. The size and spacing of the rivets are such as to permit 10 000 lb. per square inch.

The underframe is built up of four longitudinal sills extending between the body bolsters. The side and center sills are built up of 3/8-inch web plates with inside and outside top and bottom chord angles and 13-inch by 5/8-inch top and bottom cover plates, as shown on accompanying drawing. The sills are secured to the body bolsters by suitable angle connections. The outside angles of the side sills extend beyond the bolsters and are continuous between the end sills to which they are secured by means of angle connections. The sill web plates are spliced, as shown on the drawings and the splices properly strengthened by means of plates having a sufficient number of rivets to transmit the shear at these points.

The end sills are made of 12-inch by 20.5-lb. channels shaped and applied as shown on the drawings. The draft sills are made of 3/8-inch steel plates reinforced by outside bottom chord angles. The plates are flanged at the top and riveted to the floor sheets. The strength of the draft attachment conforms to the latest recommendations of the American Railway Association and the ratio of unit stress to end load does not exceed 0.05.

The cross ties, four per car, are built up of structural angles and plates. Top and bottom angles of the cross ties extend between top and bottom cover plates of center and side sills. The web plates extend between the web plates of the center and side sills and are secured thereto with proper connection angles. Each cross tie is provided with 3/8-inch bottom cover plate riveted to the center and side sills and cross tie bottom chord angles. Cross tie top chord angles are riveted directly to the floor plates.

The body bolsters are made of two 12-inch I-beams with top and bottom cover plates and suitable spreaders securely riveted together. The bolster cover plates form connections for the longitudinal sills and the draft sills. The construction is clearly shown on the drawing.

The floor sheets are made of 1/2-inch steel plates extending between the loading angles and spliced at the center cross ties. They project 10 inches outside the side sills, giving a width over the floor of 9 ft. 0 in. The floor sheets are securely riveted to the sill top chord angles; rivets are countersunk in order to obtain a smooth surface. The end floor sheets are made of 1/4-inch steel plates and are applied at each end of the car, extending from the loading angles to the end sills. They are riveted to the longitudinal sills, bolsters, draft sills and end sills as shown on the drawings.

The floor sheets are covered with 2 1/4-inch yellow pine flooring for a distance of 4 ft. 6 in. inside of the body bolster and extending to the face of the end sill. The flooring is securely bolted to the floor plates with 5/8-inch bolts with heads drawn flush. Each bolt is provided with standard nut and grip nut.

The general dimensions of the car are as follows :

Distance, center to center of bolster.	38 ft. 0 in.
Height from top of rail to center of drawbar	2 ft. 10 1/2 in.

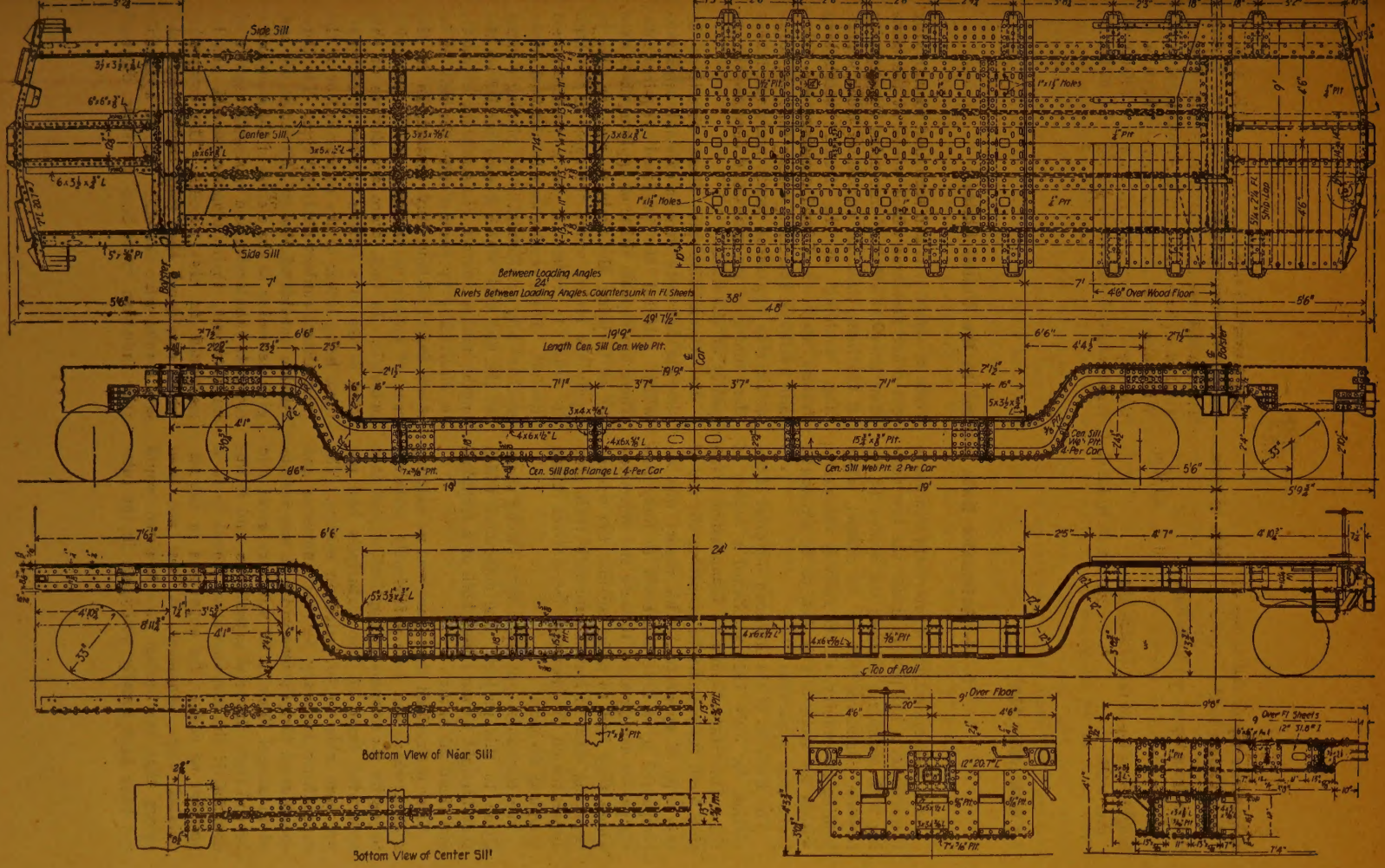

Fig. 11. — General drawing showing construction of the 70-ton capacity transformer car, New York New Haven & Hartford Railroad.

Height from top of rail to top of floor (loading deck)	2 ft. 2 1/4 in.	Length over end sills	49 ft. 0 in.
Height from top of rail to bottom of sills	0 ft. 8 1/4 in.	Length over striking castings	49 ft. 7 1/2 in.
Height from top of rail to side sill over truck	2 ft. 10 1/2 in.	Truck wheel base	5 ft. 6 in.
		Total wheel base	43 ft. 6 in.
		Width over floor	9 ft. 0 in.
		Capacity	140 000 lb.
		Light weight or car	67 000 lb.

[656 .253 (.73)]

5. — Automatic train control in the United States.

As is well known, the « Interstate Commerce Commission » has powers under the law dealing with commerce between the States (« Interstate Commerce Act ») to compel, after holding an enquiry, all the railway companies within the scope of this Act, to fit automatic train stop apparatus.

The *Bulletin of the Railway Congress Association* for July 1922 published a report of the « Interstate Commerce Commission » setting forth the reasons for requiring the use of this type of apparatus. This report was accompanied by a note addressed to forty-nine companies asking them to state the objections which they had to make against the scheme requiring them to install automatic train stop apparatus on the passenger locomotives of one complete division.

The companies put up a very strong opposition to this project. The objections which they brought forward were both of a technical and financial nature.

They maintained that there was no existing system which had been sufficiently perfected to justify its compulsory application, and that apparatus based on new principles had not yet been able to be tested in service. The expenditure necessary for the numerous and complicated installations which it was intended to compel them to fit was very great and beyond their financial capabilities, and it was doubtful if the manufacturers would be in a position to deliver the apparatus in the stipulated time. Moreover, it had not been shown that the outlay thus incurred would not have been equally well spent in the interests of safety if it had been used for carrying out other measures which would at the same time have the effect of increasing the capacity of the lines, such as, automatic block signalling, doubling of the track, interlocking frames, abolition of level crossings, etc. Certain railways expressed a fear that the automatic stop apparatus would moreover hinder the running of the trains and decrease the capacity of the lines.

The Commission met these objections by showing that there were in existence apparatus which fulfilled the proposed requirements. These are capable either of applying the brakes so as to bring the train to rest, or else to apply the brakes where the speed is too high in order to reduce it to a predetermined amount. These results may be obtained either mechanically or electrically by placing a ramp on the line with which a shoe carried on the engine makes contact (intermittent contact), or electrically by contact with the rail, or in other cases without any contact, as in the case of apparatus working on the inductive principle. In fact, there are devices of this kind in use on a certain number of railways, these being either of the mechanical or of the intermittent contact electrical type. The Commission considered that if the latter did not give, according to the claims of the companies, complete satisfaction and were still capable of improvement, their adoption should not be postponed on this account. The companies which considered that they could obtain the best results with the other type of apparatus (the inductive type) had at their disposal

plenty of time to test these, and that there were moreover a number of systems already being experimented with.

As regards the argument based on the increased expense, the Commission set off the very considerable compensation that a number of the companies had had to pay on behalf of people killed or injured as the result of accidents which had occurred during the last few years, to which compensation must be added for damage done to rolling stock and contents of wagons. If the adoption of the automatic block system has allowed the capacity of the lines to be increased by increasing the speed and the number of trains, the risk of accidents has also been increased, because the observation of the signals depends solely on the vigilence of the footplate staff.

As regards the influence on the capacity of the lines, the « Interstate Commerce Commission » admits, according to a paragraph contained in the report of the Commission nominated by the « Railroad Administration » (which took over the management of the railways during the war) that the application of the brakes should take place at a distance such that the train should stop in every case before reaching the fouling point, and that therefore the distance at which the brake is to be applied should be suitable for any train which may have to run on the line. This may lead, on lines which have a very heavy traffic, to a decrease of capacity, but it is observed that this difficulty can be overcome by means of arrangements which allow the driver to release the brakes, or else by means of an apparatus which instead of causing a dead stop, only comes into operation if the speed is too high, and merely has the effect of reducing the speed. Speed control apparatus may be employed in conjunction with the automatic train stop apparatus.

Finally, the Commission, by an order dated the 13 June 1922, required that this scheme should be carried out, and fixed the 1 January 1925 as the date by which the apparatus should be installed.

Since then, it has not changed its attitude, for we are informed that without waiting for the expiration of the period for putting into force its former requirements, it has just made a considerable addition to these. In a new order dated the 14 January 1924, it required ninty-two companies to fit automatic train stops or speed control apparatus over a complete division. Among these ninty-two companies are the forty-seven companies already included in the first instruction and which have therefore to install the apparatus over two divisions. The additional apparatus required is to be in operation by the 1 January 1926.

The Commission justifies this new measure by saying that the safety of the public and of the rolling stock makes it necessary that the protection resulting from this kind of apparatus should be increased as quickly as possible over additional portions of line.

The order lays down a schedule of the conditions which the apparatus must satisfy. Our readers will find the text given in the July 1922 number of the *Bulletin* mentioned above.

E. M.